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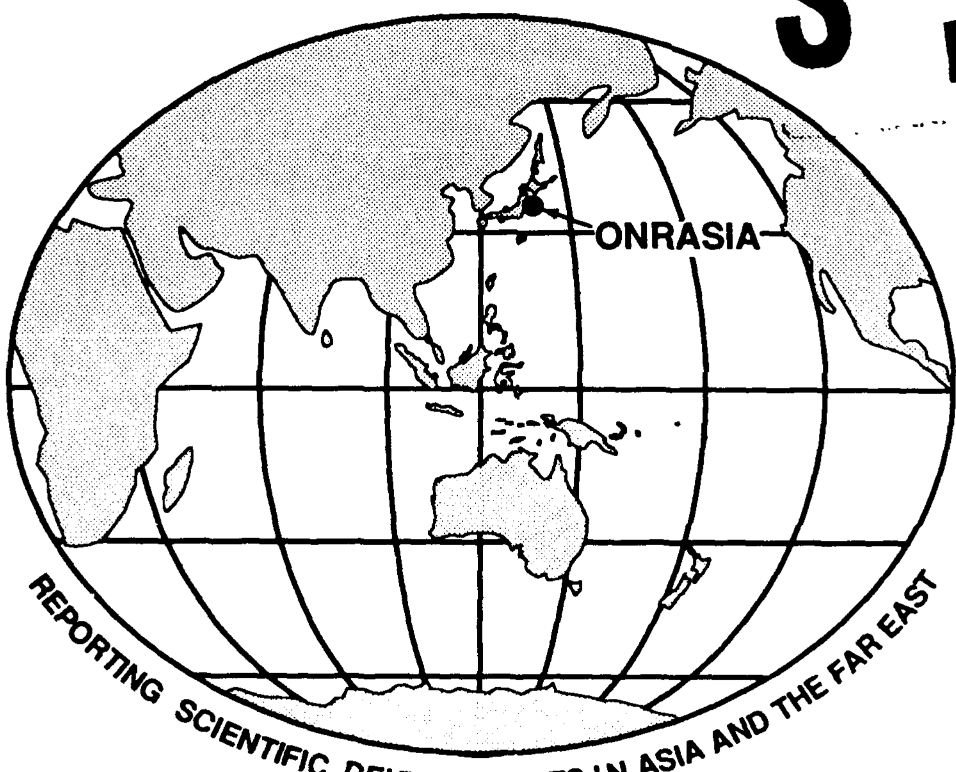

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This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONRASIA, with certain reports also being contributed by visiting stateside scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest. This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large. It is available free of charge to approved members of the DoD scientific community. Send written request describing DoD affiliation to: Director, Office of Naval Research, Asian Office, Unit 45002, APO AP 96337-0007.

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SIBRIEFS

Scientific Information Briefs

COMPUTER GRAPHICS INTERNATIONAL 1992, 22-26 JUNE 1992, TOKYO

An earlier report ["cgi.92", 29 July 1992] listed the program in detail, as well as names and addresses of the organizers. Here we give a summary of key papers and directions. The following report was prepared by

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CG INTERNATIONAL 1992 VISUAL COMPUTING

Integrating Computer Graphics with Computer Vision, June 22-26, 1992 Kogakuin University Tokyo, Japan.

The Technical sessions of the conference covered a broad Spectrum of topics that included:

- — Volume visualization
- — Isosurfaces
- — Rendering
- — Virtual reality
- — Simulated nature
- — Dynamic and Kinematic Modeling
- — Sweep methods
- — Model Based coding
- — Interpolation and fitting
- — Rules and Constrain Based Modeling
- — Hidden surface and Hidden curve algorithms
- — Raster technology
- — Animation
- — Computer Aided Geometric Design
- — Tools and Programming Environments

Because of this large number of topics, very few papers were presented in many of these topics. In addition, there was an invited talk on Holographic Video and two invited talks about the title theme of the conference; "Integrating Computer Graphics with Computer Vision". The first of these talks was by professor A. Rosenfeld of the University of Maryland, who presented his qualitative views that the link between the Computer Graphics and Computer Vision is the advanced data structure or the models they use.

The second talk was given by Professor Encarnacao who described the experience and on-going programs at the Technical University of Darmshtadt in cooperation with other European countries in using multimedia, visualization, and computer graphics techniques in distant education and industrial training.

The Conference keynote address was by Mr. I Wasaki (the senior vice president of NTT, Japan) who presented the Japanese interest and determination to develop the telecommunication in the 21st Century to become more *visual, intelligent and personal*. The paper outlined the research and development activities carried out by NTT to bring the VI&P concepts to reality by the early years of the 21st Century. The plans are to complete the development of high-speed optical fiber, broad band (B-ISDN) early in the 2000s for all business users, and by the 2015 for all households throughout Japan.

This trend is very similar to that in the United States and Europe; although, I am not aware of as clear a plan in the United States as this talk lead me to believe exists in Japan.

The volume visualization session consisted of four papers, one from the West (Norway) and three from the East. The four papers aim at speeding up the computation processes. The paper by Giertsen (IBM, Norway) describes the use of a scan plane buffer associated with each scan line. This buffer maintains the individual contributions to the pixel values of the scan line. Further, the geometric primitives are scan converted and the results inserted into a single scan line multiple layer Z-Buffer. Final pixel values for the scan line are determined by merging the two buffers.

The second paper by Shu and Chui (Singapore) suggests an incremental approach to approximate the trilinear interpolation in a ray casting technique for volume rendering that is twice as fast as the usual trilinear interpolation process to determine the densities of the sample points along a ray for the same image quality. Another efficiency improvement in the cost of volume reading was presented by Koyamoda (IBM,

Tokyo). The idea here is to divide the volume into a set of tetrahedral cells. The amount of calculation is reduced by using the exterior faces of cells rather than the ray as the base for processing. The use of Ray Casting Technique in the rendering of density clouds and surfaces is described by Handana and Takada (both of NEC, Japan).

The paper by Tanaka (ATR, Japan) on the visualization of Complex shapes from sparse and incomplete range data is quite impressive. The technique is based on differential geometry using adaptive and arbitrary oriented meshes.

Rendering of outdoor scenes by Professor Nakamae reports a very impressive effort at Hiroshima University; they have been constant at work in this problem for a number of years. Their results are maturing very nicely.

A group from different Japanese Universities presented a method to render curved surfaces under illumination of parallel cylindrical light sources and to compute the shadows they cast under these conditions. The work is successful in producing quite realistic images.

The highlight of the virtual reality session was the paper by Takemura and Kishino (ATR, Japan). Their paper describes a case study of building, a prototype of cooperative work environment. An implementation of an environment where two operators can grasp and move by hand an image is presented. The System uses a hand gesture input system.

Three eye-catching presentations were made in the simulated nature session. Modeling of compound leaves from the University of Calgary, simulating bird's eye views from Carnegie Mellon, and synthetic fire works from Japan.

Talking about the subject of Computer Animation, this could be accomplished on the basis of kinematics only. This approach often produces unrealistic results and always requires the animator to be heavily involved. More realistic results can be obtained by considering the physical laws and the dynamics of the motion. The obstacle in this approach is the complexity of the models and the computational cost associated with it. At this conference, a number of papers addressed the problem differently, thus overcoming the obstacle.

Chua (University of Singapore) presented an adaptive time-step solution scheme for the equation of motion, for rigid and elastic bodies that include a treatment for avoiding collision. The paper, as expected, is mathematical in nature, but the presented animation case of free falling elastic sheet is very interesting.

The paper by Amakawa (University of California) addressed the animation of multijoint arm through training a neural network.

Two invited papers were also presented on the same subject of computer animation. Each paper had been authored by one member of a couple, Nadia and Daniel Thalmann of the University of Geneva. Daniel presented the animation of growing objects by using L-system. He simulated the interaction with the environment (e.g., existence of wind) through the use of a vector force field.

Nadia's talk concentrated on the simplification of parts of the objects through the modification of polygonal meshes. Her objective was to reduce the complexity of the animation of the human body motion and the collision of clothes with it during motion.

From the world of animation, the conference turned to the subject of generating 3-D objects by sweeping 2-D ones. A very involved paper by three Korean authors discussed an algorithm to compute an approximation to the general sweep boundary of a 2-D moving object that changes its shape while traversing the trajectory. The method depends mainly on polygonal approximation of the trajectory and the object shape at various points along the trajectory. Each two consecutive instants are linearly connected, then polygons are constructed to approximate the sweep boundary.

Another paper by professor Kunii of Japan with two young researchers from Singapore was also presented; Kunii was the Japanese organizer of this conference. The paper describes the integration of the sweep technique with the Homotopy model through the use of one parameter that controls the sweeping as well as the deformation of the cross section shape. The results are quite good.

The sessions on "Model Based Coding" contained five papers, all from Japan. Four of the five papers, related to description, Synthesis and Control of facial expressions. In one paper a description is given of a method for the creation of a model and synthesis of facial expressions by using isodensity maps; the technique seems quite successful. Another paper describes the use of input text to control the motion, expression, and mouth shape. The synthetic actors are capable of talking with synchronized correct mouth shape of the sound. The demonstrated results are interesting and impressive. Another paper described a hardware system and software algorithm for visual interactive control of synthesized facial images using finger signs. This required a substantial amount of work by two young researchers from the University of Tokyo.

Face-to-Face communication between the operator and the synthetic actor was the subject of a

paper by two researchers from Tokyo University and Seiki University. The paper presents a prototype of multimedia man-machine interface based on the media conversion scheme.

At the hidden surface and hidden curve session, a good paper by three Japanese professors from three different Japanese Universities was presented. Their algorithm used Bezier clipping, rather than the common polygonal approximation, for the computation of hidden surfaces, interaction of curves, calculation of penetration points, and the extraction of contour lines.

In the above, I didn't try to describe all the papers that were presented. My aim was rather to highlight the conference's important papers and those that reflect today's interests, and also to report on major activities. -- *David K. Kahaner, ONRASIA*

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WORKSHOP ON MODERN GEOMETRIC COMPUTING FOR VISUALIZATION, JUNE 1992 TOKYO

This workshop was held one week after the large Computer Graphics International meeting, held 22-26 June 1992, see my report ["cgi.92", 29 Aug 1992]. The workshop represents the theoretical end of the visualization research area—papers were primarily devoted to combinatoric, topological, singularities, and related aspects of visualization and modelling. A Proceedings containing all the papers was carefully prepared and has been published as follows, therefore I will not review this material in detail but only make a few summary comments.

Proceedings:
Modern Geometric Computing for Visualization
T.L.Kunii & Y.Shinagawa (Eds.)
ISDN 0-387-70105-2,
Springer-Verlag New York,
1992.

Computer visualization requires the computation of various displayable shapes, which are becoming more and more complex along with the objects and phenomena that scientists are trying to visualize. Computation must be fast, and this requires information locality. Such information locality is achieved by characterizing the shapes via geometry and topology, and this may need substantial computation that requires supercomputers, but the fundamental tool remains reasoning about geometry. Thus it was not surprising that the most impressive papers were about theoretical tools such as Fomenko's (Moscow) paper on topological classification of Hamiltonian systems, Kergosien's (Paris) on shape modelling through singularity theory, Patrikalakis' (MIT) also on singularity theory for engineering design, or Kunii's (Tokyo) on Homotopy models for a geographical database system. Earnshaw (Leeds) described current scientific visualization work in the UK, actually a very good survey of existing tools and trends. But the high level of other research described at this workshop was emphasized by T.Kunii, who commented to Earnshaw that it was crucial to have a scientific core for any group of research activity.

Readers should note that Patrikalakis' work was supported by the Office of Naval Research (ONR).

I would like to call attention to several papers.

Kergosien's work is a careful and complete introduction to Morse theory, Reeb graphs, singularity theory and related algebraic topology as it applies to visualization.

The paper by Mori from Ricoh on shape description of characters based on their extremal points. The application here is a faster scheme for optical character recognition. Mori's technique contrasts to that based on Morse theory, and what is impressive here is both the nuts and bolts experimentation that the authors have done as well as the high level of scholarly work from scientists at a company that is usually not highly thought of by the West. (Recently, Mori has also written a survey to be published this year by IEEE: Mori S., Suen CY, Yamamoto K., "Historical Review of OCR Research and Development," IEEE Proceedings, 1992 (in press).

Fomenko's paper contained some of the deepest analysis, including new results in computer geometry, Hamiltonian mechanics and symplectic topology (in particular studies of the enumeration, recognition, and algorithmic classification of all integrable Hamiltonian systems). Two papers were presented by Melnikov on the development of supercomputers in the former Soviet Union, including a 4 cpu system with 500 MFLOP peak performance. Melnikov is the Director, Institute for Cybernetics Problems, Russian Academy of Sciences. He also described some of the Institute's more current research, including a PC-based handwriting recognition system. Melnikov spoke in Russian, using overhead transparencies of marginal quality. A translator was present, but it was slow going. Fortunately both papers are included, in fairly good English, in the Proceedings, and these represent an important historical record. Although these papers were included in a section titled, "Supercomputing for Modern Geometry," the link to this workshop was very tenuous. Nevertheless, it was a fascinating presentation by someone who was in at the

very beginning of the USSR's high performance computing program.

The workshop chairperson was

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who was also the organizer of CGI-'92. Kunii is very well known in the West. Along with his students and colleagues, three coauthored papers of his were presented within the application session, including two related to the construction of geographical databases. Many researchers have been interested in terrain visualizations systems for over a decade, but because of the tremendous amount of data, efficient representations and data structures are required. One approach is to somehow employ the concept of a fractal, by determining the fractal dimension of the given terrain data. A disadvantage of this method is that no topological characteristics of the terrain are included, and hence the geometrical characteristics of the terrain are difficult to capture. One research direction of Kunii is to use the homotopy model to describe the terrain in the form of a series of contours and, with certain simplifying assumptions, makes use of the Reeb graph of a 3-D object. In a related paper some guidelines are proposed for the development of a global (geomorphological) database with a 250-m mesh. Finally, a third paper presents a method for reconstructing surfaces from cross-sectional contours based on surface coding theory, also related to Morse theory. These papers involve complicated concepts and difficult mathematics, but have significant potential applications.

Program, Modern Geometric Computing for Visualization
Tokyo, Japan, June 29-30, 1992
Kogakuin University

SESSION 1: *Modern Geometric Classification and Its Computation*,
Computer Geometry and Topological Classification of Integrable Hamiltonian Differential Equations: Visualization of Concrete Physical Examples (invited paper)

A. Fomenko (Dept. of Geometry and Topology, Faculty of Math & Mech, Moscow State Univ, Moscow, 119899, Russia. Email: ANATOLY@FOMENKO.MIAN.SU)

The Conjugate Classification of the Kernel Form of the Hexagonal Grid,
Z. J. Zheng and A. J. Maeder (Victorian Center for Image Processing and Graphics, Dept of Computer Science, Monash Univ, Clayton Vic. 3168, Australia)

Shape Description and Classification Based on Extremal Points and Their Relations,
Y. Nakajima, S. Mori and H. Nishida (612RG AI Tech Dept., Ricoh R&D Center, 16-1 Shin-ei-cho Kohoku-ku, Yokohama, Kanagawa 223 Japan)

Automatic Parallelization of Programs for MIMD Computers (invited paper),
V.A. Melnikov, B.M. Shabanov, P. N. Telegin and A.P. Chernjaev (Institute for Problems of Cybernetics, Russian Academy of Sciences, Vavilova St. 37, Moscow, Russia) also (Russian Academy of Sciences, 9, Prospect 60-let Octyabria, 117312 Moscow, Russia, Email: BRITKOV@ISI.MIAN.SU)

SESSION 2: *Modern Geometry for Visualization*,
Interdisciplinary Techniques, Toolkits and Models for Scientific Visualization (invited paper),
R.A. Earnshaw (Head of Computer Graphics, Computing Service University of Leeds, Leeds LS2 9JT, United Kingdom, Email: ECLRAE@CMS1.UCS.LEEDS.AC.UK, or R.A.EARNSHAW@LEEDS.AC.UK)

Visualization of Hyperobjects in Hgram-Space by Computers,
Y.M. Pok and Y.K. Huen (EE Dept, Ngee Ann Poly, 535 Clementi Road, Singapore 2159)

Topology and Visualization Structures (invited paper),
Y.L. Kergosien (Dept of Math, Bat 425, Univ of Paris-Sud, 91405 Orsay, France)

SESSION 3: *Modern Geometric Analyses of Visual Information*,
Polyhedral Surface Decomposition Based on Curvature Analysis,
B. Falcidieno and M. Spagnuolo (Istituto per la Matematica Applicata del C.N.R., Via L.B.Alberti, 4-16132 Genova Italy, Email: {FALCIDIENO, SPAGNUOLO}@IMAGE.GE.CNR.IT)

Motions of Flexible Objects,
D. Roseman (Dept of Math, Univ of Iowa, Iowa City, Iowa 52242 USA, Email: ROSEMAN@DIMENSION4.MATH.UIOWA.EDU)

Using Surface Coding to Detect Errors in Surface Reconstruction,
Y. Shinagawa and T.L. Kunii (see above for Kunii's address)

SESSION 2: *Applications of Modern Geometry*,
Computation of Singularities for Engineering Design (invited paper), N.M. Patrikalakis, T.Maekawa, E.C. Sherbrooke and J.Zhou (Dept of Ocean Engineering, MIT, Room 5-428, 77 Mass Ave, Cambridge, MA 02139-9910 USA,
Email: NMP@DESLAB.MIT.EDU)

A Geographical Database System Based on the Homotopy Model, T. Ikeda, T. L. Kunii, Y. Shinagawa, and M.Ueda (See above for Kunii's address)

A Case Study for Establishing Better Geomorphological Database, M. Ueda, T.Ikeda, T. L. Kunii and Y.Shinagawa (See above for Kunii's address)

The Development of the Supercomputer System Electronica SSBIS (invited paper),
V.A. Melnikov, Y.I. Mitropolski (see above for Melnikov's address)

Closing Remarks: T. L. Kunii, Program Chairperson Conference Organization

Computer Graphics Society,
Kogakuin University,
Japan Personal Computer Software Association,
Department of Information Science,

The University of Tokyo in cooperation with

Information Processing Society of Japan,
The Institute of Electronics, Information and Communication Engineers

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Foundation for the Promotion of Local Education and Science in Aizu,
Kubota Computer Inc.

-- *David K. Kahaner, ONRASIA*

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SCIENCE AND TECHNOLOGY AGENCY (STA) SURVEY ON JAPANESE MANUFACTURING RESEARCH AND DEVELOPMENT, 2 JULY 1992

The Japanese STA recently concluded an investigative report on the research activities of Japan's private sector manufacturing firms. In compiling this report, the STA surveyed 1,301 manufacturers with a level of capitalization over 1-billion yen, eliciting a 63.9% response. According to the results of the investigation, R&D expenditures of the respondent companies totalled 7,402.20-billion yen against sales of 207,700-billion yen in 1990. The average level of R&D expenditure per manufacturer was 8.9-billion yen. By industry, average levels of expenditure in billions of yen was as follows:

- Automobile 23.1
- Communications, electronics 21.3
- Electric machine tool 21.0
- Electronics 21.0

Among the respondents, the averege ratio of R&D expenditure to sales overall was 3.6%. The medical industry led in this area with a ratio of 11% followed by the communications, electronics and electronic measuring instruments industries at 8.6%. The ratio for the precision machine industry and the electric machine tool industry stood at 6.7% and 6.5% respectively.

STA used the responses to estimate the actual number of researchers working for manufacturing companies. The number was 215,000. The communications, electronics and electronic measuring instruments sector led in this category with 701 researchers per company. This same sector also led in percentage of employee involvement with 13.7% of payroll expenditures involved in R&D. This figure was more than double the average for all industries, which stood at 6.2%.

Information submitted to STA over the course of this survey indicates that Japanese manufacturing companies held approximately 369,000 domestic patents. A breakdown of this figure by industry shows that an average of 1,612 domestic patents are held by each company in the communications, electronics and electronic measuring instruments sector. As a function of capitalization, an average of 92 patents are held by manufacturing companies capitalized at between 1- and 5-billion yen, and an average of 3,499 patents are held by manufacturing companies capitalized at over 100-billion yen.

According to STA, average R&D expenditures at overseas subsidiaries where Japanese manufacturing companies have over a 50% ownership stake stands at 367.9-billion yen. This figure is equal to approximately 1.28% of sales for these companies. The automotive sector spent most on R&D overseas, and it was followed by the electric machinery sector.

This survey also included a series of questions designed to illustrate some trends in international R&D activity by the Japanese manufacturing companies. The survey revealed that a group of 117 Japanese manufacturing companies have a total of 276 R&D facilities located overseas. A breakdown of this number by industry shows that 19 manufacturing companies in the electric machinery sector have a total of 54 facilities overseas. The precision machinery sector ranked second with 13 manufacturing companies that have a total of 36 facilities. While the majority of these facilities have been located within the United States, future planning on the part of Japanese manufacturing companies indicates a trend towards locating new R&D facilities within Europe and the Asian countries. The necessity of improving products to meet consumer needs was the most frequent justification given for the decision to locate R&D facilities overseas.

This survey uncovered some interesting attitudes within Japanese manufacturing companies towards technology transfer. According to survey responses, 36% of Japanese manufacturing companies expected that "technology can be expected to be both exported and imported." On the other hand, 13% of the companies responding expressed the expectation that technology "can be expected only to be exported," 15% stated that "it will only be imported,"and 36% stated that "no technology transfer will occur." Regarding the destination to which technology would be exported, 43% of Japanese manufacturing companies stated that it would be exported "only to companies other than our subsidiaries," while 27% chose the response "more to companies other than our subsidiaries."

As part of this survey, participating Japanese manufacturing companies were asked to rank the different regions of the world in terms of comparative R&D capabilities over time. Results of these questions indicate that at present, most Japanese companies still perceive the United States to have the strongest R&D capabilities, Europe follows, and Japan is in third place. But, five years in the future, Japan will supersede both the United States and Europe.

Finally, the survey indicated that most Japanese manufacturing companies expect competition among the United States, Japan, and Europe to continue and tension to increase. In an attempt to identify countermeasures to this expected increase in tension, 36% of Japanese manufacturing companies suggested cooperation in research and development, 28% suggested technology transfer, and 12% suggested the establishment of overseas research facilities. -- *Daivd K. Kahaner, ONRASIA*

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OKI ELECTRIC'S SOFTWARE IMPROVEMENT ACTIVITIES

In a recent report, ["oki.ps", 9 May 1992], I described some of the software production research that was going on at Oki Electric. The techniques that large Japanese software producers use to address problems of creating, managing, and maintaining software are clearly of interest to others. A recent book,

Japan's Software Factories,
Michael A. Cusumano,
Oxford University Press, 1991

contains many anectodal descriptions of how this is done in Japan.

Scientific readers of my reports should note that the largest software products, containing millions, or even tens of millions of lines of source program text, are often found outside the technical arena, in securities, insurance, and other financial industries. Communication and command and control software can also be massive.

Recently, I was accompanied by

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on a visit to Oki to hear about their recent efforts firsthand. (Oki is not one of the companies that Cusumano details in his book.) Obviously, Motorola is interested in software management, as very large fractions of the value added aspects of their cellular telephone infrastructure are due to software. Mr. Willey commented that companies are looking for ways to reduce the dependence on software *stars*, because of the high risks that individual organizations incur when people leave, become ill, etc.. These companies are also trying to verify and understand the Japanese software developers claims of 10% productivity improvements annually.

I wish to thank Mr.Willey for his summary of his visit, which I have merged into the report below.

For those people not familiar with Oki, this was Japan's first private telecommunications manufacturer that produced a prototype telephone in 1881, barely five years after Bell's invention. Last year Oki's sales amounted to 661 Billion Yen, close to US$ 5 Billion, and has slightly more than 20,000 employees. Oki has three main business activities,

- Telecommunication Systems,
- Information Processing Systems, and
- Electronic Devices.

Oki is one of the largest manufacturers of telemetry and telecontrol equipment, including aircraft and marine control systems. Also, they are leaders in navigation systems for automobiles as well as for marine applications. The Japanese submersible Shinkai is equipped with Oki developed acoustic navigation systems and underwater imaging systems.

Software activities are associated with many aspects of Oki's business, but especially with communication software such as PBX, networks, switching systems, ATM systems, etc. Many of these systems must work in real-time. We were told that a recent product had about 1.2 million lines of code, and another PBX software project had 400,000 lines. Currently Oki has about 6,000 employees that are considered software engineers. (Willey explained that the corresponding figure for Motorola is about 8,000.)

We visited the research activity of Oki Electric Industry Co., Ltd. at

10-3, Shibaura 4-Chome,
Minato-ku, Tokyo 108, Japan
and we were hosted by
Mr. Yasufumi Nanae
Director
General Manager,
Corporate Software Planning
and Engineering Div.

Mr. Teruo Uchida
General Manager,
Software Production
Engineering Center
Corporate Software Planning
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Willey presented an overview of Motorola's activities and a general summary of an earlier Motorola team trip that he made to Japan to study software production methods. Mr. Nanae, who also had a copy of Michael Cusumano's book, expressed his opinion that the Motorola teams' overall findings with respect to the companies they visited in Japan were essentially the same as those Dr. Cusumano expressed in his book.

He also confirmed that measured software productivity improvements ranged 7 to 13% annually, but that such gains would not continue without new tools. Willey feels that what is now needed is to look beyond the now-famous *software factories* described by Cusumano to discover what else is happening in Japanese software.

Mr. Uchida presented materials that described *OPENS* (Oki Software Production Environment Enhancement Strategy). Essentially, he presented an update to materials that were originally presented in May, 1991 in the OKI Technical Review, which was summarized in the report mentioned above.

Oki's Software Improvement Strategy

Mr. Nakae reported that in April 1992, he had been appointed to his current position as General Manager, Corporate Software Planning & Engineering Div. at Oki. This was a newly created position to serve as the focus for software improvements. He was responsible for the Software Production Engineering Center operated by Mr. Uchida, and also for the technical training and education program for software professionals at Oki.

Willey concludes that this indicates that Oki, like many other major Japanese corporations engaged in software development, has made a decision to commit significant resources for the improvement of their software production resources. As a Oki corporate Director, Mr. Nakae would have significant visibility, and appears to have been given a charter with enough resources to make it happen. For example, we were told that Oki's goal is one workstation for each engineer.

Oki Software Production Environment Enhancement Strategy (OPENS)

Oki has adopted a very ambitious long-term plan to develop appropriate environments for its software engineers. It is clear that several years, thought, have gone into the evolution of the ideas contained in OPENS, and real corporate commitment exists.

OKI's presentation materials covered the following:

OPENS Goals:
- Establishment of Advanced Software Engineering Environment
- Distributed and Seamless Environment
- Effective Management
- Improvement of Information Services

OPEN for OKI group
OPEN architecture
OPEN mind for users
OPENS is built on the SENNA Model (Software engineering ENvironment and Network Architecture)

Oki provided us a graphic that demonstrated a 3-D view of an environment for engineers.

The SENNA Model resembles, in many respects, MCC's Leonardo—in fact, Les Belady has clearly had a significant impact on their thinking. (Belady has an article on Leonardo in the Oki Technical Review mentioned above.) Willey worries that "we seem to be in danger, here, of having the good ideas we paid to have MCC develop for us used by our global competitors before we have effectively implemented them ourselves."

OPENS features a "development support system"

The *development support system* is tailored for four *styles*

1. *Universal* Method Environment: Constructing with general purpose concepts

2. *Reuse* Method Environment: Customizing (Modifying) similar systems

3. *Mass-Production* Method Environment: Domain (Target)-specific Automated Systems

4. *Porting* Method Environment: Porting to other machines

While Oki talked about the different *Method Environments* that would be supported by using the SENNA Model tailored for these *styles*, our impression was that these were conceptual, and had not yet, in fact, been implemented for many of Oki's software developers.

We were given some examples of the kinds of projects that each of the four styles would be used for. No. 1 was used for medium-sized projects such as switching or transmission systems, No. 2 was used for navigation systems and to bring together various banking modules, No. 3 was used for ATM systems, and No. 4 for porting an operating systems to an Oki-developed workstation.

Two specific *Method Environments* were described briefly.

1. SDL Method Environment

SDL (Specification & Design Language) is a CCITT-supported ISO Standard high-level language particularly applicable to key aspects of telecommunications (where a state machine controller is required). Since Oki is in the telephone switching business, where such applications are common, it is not surprising that they would plan such an environment.

Although the overview of the SDL Method Environment was very high-level, it appears that they are well along in creating an environment in which the SDL specifications can be turned into C++ via an automated code generator. We were told that a manuscript describing this activity was to be presented, October 1992, at the International Switching Symposium in Yokohama Japan.

2. Structured Method Environment

This *environment* seemed much less advanced than the SDL Method Environment in two ways. First, it appears that what they are attempting to do is to create a *framework* into which to *glue* a set of commercially available tools. Little creative work seems to be going on to either develop internal tools, or to enhance the functionality of the tools purchased through efforts to carry out a through-designed implementation. Second, the use of Structured Methods for software engineering is now 15 years old, and it is "behind the times" when compared with current object-oriented (C++ vs C) applications development efforts.

SUMMARY

Oki is committed to improving the productivity of their software engineers. They have a long-term plan, and have allocated significant resources. Their plan looks much like MCC's Leonardo, but it is early in its implementation phase. -- *David K. Kahaner, ONRASIA*

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AIRCRAFT COMPUTATIONAL AERODYNAMICS, 29 JUNE 1992

For the following material, I am very grateful to

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Dr. Hirose emphasized to me that the comments below are his personal view and not necessarily those of the National Aerospace Laboratory (NAL) or the Japanese Government.

Hirose recently presented a paper at the Third ISNaS Symposium held on 19 to 20 September 1991 (NLR Noordoostpolder, the Netherlands) "Numerical Wind Tun-

nel (NWT) project and Computational Fluid Dynamics (CFD) at the NAL, Japan". It is an excellent historical description of the work at NAL including their computing experiences and general directions of CFD research. This is in English, so I will not summarize it here except to point to NAL's ideas about a NWT, a project to enhance their computing power with a system focused on their specific needs. (Readers can write to me or to Hirose for full copies of this paper.) Requirements estimation for NWT:

1. Main memory
   a. Grid points:
      (1) For full configuration analysis with engine, flaps, and SRB.
      5-15E6 points
      (2) For practical application of LES 150E6 points
   b. Data
      (1) Conventional TANS analysis (perfect gas, algebraic turbulence model, steady flow)
      30 to 50 data per grid point
      (2) High level TANS (perfect gas, refined turbulence model) 60 to 100 data per grid point
   c. Data accuracy
      (1) 4 to 8 Bytes (4 Bytes for primitives, 8 Bytes for computation)

Result
   a. 15E6*(200-400 Bytes) = 3-6 GBytes
   b. 150E6*(200-400 Bytes) = 30-60 GBytes
   Total memory size of at least 30 GBytes is required

2. Processing speed
   a. Typical CPU time on Facom VP-400
   TANS analysis with E6 points, 10 h.
   Stiff problems (real gas, etc.) take 2 to 3 times longer.
   Average to peak speed ratio in highly vectorized Fortran code is 0.3-0.5
   b. Data productivity requirement at NASA, NAS Practical application: 10 min/data point. Research 60 min/case.
   At NAL it will be
   Practical application: 60 min/data point.
   Research 600 min/case.

Result
   Effective speed should be 150 times VP-400 average speed.

In 1991 the VP-400 was replaced by a Fujitsu VP2600 (SMFLOPs peak, 512MB) Concerning the NWT, a RFP was released in 1989, but no commercially developed machine was able to satisfy their requirements. I am told by other scientists that Fujitsu is working with NAL staff to develop a suitable system.

RESEARCH CENTER FOR ADVANCED SCIENCE AND TECHNOLOGY ACTIVITIES IN AI AND EXPERT SYSTEMS

AI and Expert System activities at the Research Center for Advanced Science and Technology (RCAST) are reviewed. RCAST is a part of Tokyo University.

David K. Kahaner

This report is another spinoff from my March 1992 visit with the Japanese Technical Evaluation Center (JTEC) team, see [hitachi.ai, 25 August 1992].

RCAST was established in 1987 in an extraordinary effort to develop a new (for Japan) kind of research organization. RCAST was to grow under four guiding principles, 1. interdisciplinary studies, 2. international cooperation, 3. mobility and flexibility of staff and research areas, and 4. openness to the public and to other organizations. It has four main departments with 19 regular chaired professors, as follows:

- Advanced systems department
  Urban environment systems chair
  Biomechanics chair
  Large scale systems chair
  Factory automation chair
  Knowledge processing and transfer systems chair
  <-- JTEC visit

- Advanced devices department
  Optical devices chair
  Biomedical devices chair
  High-speed functional devices chair
  Quantum microstructure devices chair
  Intelligent sensing devices chair
  <-- earlier (Tachi) visit
  Biosensors and bioelectronics chair

- Advanced materials department
  Chemical materials chair
  Photonic materials chair
  Highly durable materials chair
  Molecular information materials chair
  Robotic materials chair

- Socio-technological research department
  Science and technology and industry
  Information technology and industry
  Ethics of science and technology

In addition there are four guest chairs (currently functional materials—dealing with interface phenomena, new laser devices, system tero-technology, and technology assessment), and eight endowed chairs, as follows:

Frontier chemistry (Hitachi)
Quantum materials (Hitachi)
Computers and communication (NEC)
Telecommunications (NTT)
Marine biology (Toyo Suisan)
Urban development engineering (GC5)
Future system analysis (Mitsubishi Heavy Industries)

Lab facilities are augmented by a 3-m wind tunnel, a process center, which contains epitaxy and lithography rooms, a bio-clean room, and a running test center.

In addition to fundamental research, RCAST is also involved in beginning an interdisciplinary graduate course that will be open to the entire public.

There are about 80 faculties at various levels (53 professors), about 150 graduate or research students, and about 140 research fellows. The 1990 budget was approximately 1.8 Billion Yen, almost US$15M.

RCAST is adjacent to one of the *standard* University of Tokyo campuses just outside the city's central ring. It has an attractive, weathered, academic appearance. Because its location is less congested and much greener than that of the University main campus, RCAST would be a very pleasant place to spend a sabbatical or research visit.

RCAST publishes two useful periodicals, the *RCAST News* (twice a year), that contains introductory

descriptions of research activities, and *RCAST Journal* (once a year), which contains outlines and summaries of research, lists of publications, and current research status. General questions about RCAST can be addressed to

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Interestingly, Prof. Ohsuga also holds the chair of Knowledge processing within the Advanced systems department, the focus of the current report (this dual appointment speaks worlds about the administrative structure of this research organization).

I have reported on RCAST activities in the past, see for example ["tachi.lab", 9 March 1992]. Professor Tachi is in the Advanced Devices department, and under the chair of Intelligent Sensing Devices.

Ohsuga is a former President of the Japan Society for Artificial Intelligence and has been engaged in research in AI since 1970. His lab is jointly run with Koichi Hori who joined in 1988 from the National Institute of Japanese Literature (Email: HORI@OHSUGA.RCAST.U-TOKYO.AC.JP). Currently, a professor from France and 19 students are visiting; about one third from outside Japan. Although the working language is Japanese, English is widely spoken and most of the technical reports are available in English. Computer user-interfaces are mostly in Japanese however.

On the general topic of expert systems, Ohsuga pointed out that these are still fairly small scale in Japan, but the systems are being rapidly implemented by industry. He is personally interested in large systems, for example the large knowledge base that is needed by the Electronic Dictionary Research project [see "edr.92", 27 March 1992]; however, he feels that such a knowledge base can't be flat, i.e., it needs to be built as a multilevel structure. Parenthetically, the question of ICOT was brought up. Ohsuga felt that their hardware was okay, but that there were no substantial applications developed yet. He also echoed the Japanese sentiment that ICOT had been a very good advertisement for AI, and in fact had moved students away from traditional areas, to the point now that the best students in Japan seem to be moving into AI subfields. He also offered that ICOT had propelled the growth of the AI in Japanese industry.

OHSUGA LAB

Ohsuga has proposed a knowledge representation language (called multilayered logic) based on an extension of predicate logic by expanding its syntax. (Ohsuga believes that knowledge representation is the central issue in AI. He also feels that multilayered logic satisfies most requirements for knowledge representation; it is very convenient for defining structured objects, and is also convenient to describe and to link to databases and existing procedures.) The Lab has also implemented a knowledge base system (KAUS; Knowledge Acquisition and Utilization System) based on this language.

KAUS runs under Unix. It uses a special procedural atom, 'Exec', that allows cooperation between knowledge processing and conventional computing in a simple way. Exec is a second order predicate that accepts character strings as arguments. It interprets the first argument as a program name and the remaining arguments as arguments of that program. By using the fork and join mechanism in Unix, it forks a new process and runs the program, eventually returning either 'yes' or 'no' according to the end code of the program. Thus many Unix programs can mesh nicely with KAUS, including various database systems.

Ohsuga and his group have developed a variety of applications using KAUS, primarily in engineering domains, including mechanical design, feedback control system analysis, airplane wing design, chemical compound design. Some details and references are described below. What is important about this work, in my opinion, is the very close link between advanced knowledge processing concepts and traditional engineering issues. Most of the students working in Ohsuga's lab are trained in computer science, not engineering. Nevertheless, the lab as a whole has a strong bias toward practical problems as seen by the applications they are studying. RCAST's philosophy emphasizes openness. When it is coupled to the quality of the work that is occurring there, collaborative activities with Western scientists are bound to be fruitful.

A special interest at this lab is the intelligent CAD systems, i.e., the development of knowledge-based CAD system. In one feedback control system application, the system offers the designer a diagram language to define an object model of a control system with block diagrams and mathematical expressions. Routine tasks such as deriving transfer functions and calculating time responses, are mostly done automatically. The system is distributed by using various computing facilities on a network. Such feedback control system design involves two kinds of man-machine cooperative activities—one to build the control system model in the computer, and the other to determine various physical

parameters based on the model (time responses, frequency responses, root locus, relative stabilities, etc.).

We were also told about the prototype aircraft wing design system developed by using KAUS. Ohsuga pointed out the difficulties associated with such designs, and that it may require as many as ten years for complete design and manufacture, and that it may require not only numerical and large scale database processing but also knowledge processing and model processing. The prototype system has two numerical packages, one for aerodynamic and the other for structural analysis, but other packages can obviously be added. A database of NACA wing sections is stored as standard wing sections and can be referred to by designers, or they can add their own wing sections to the database. A wing model consists of an aerodynamic and structural model. In aerodynamic design, designers first make an initial model that specifies the shape of the wing, then they analyze and modify this, repeatedly, until goal characteristics such as lift, drag, and moment are obtained. In structural design, designers first make an initial model that specifies the wing framework constructed by beams and ribs, then they analyze and modify it until the wing has enough strength. In case it isn't possible to obtain a strong enough structural model, the aerodynamic model must be modified. Since both models are integrated into this system, consistency can be maintained. Associated with this project is a package, MODIFY (Modeling tool for Integrated Finite element analYsis), developed in the lab. This is an object oriented FEM system, which uses parts objects, and the concept of *degree of importance* to help with mesh generation.

One of the most interesting papers on this subject appeared in *Computer Aided Design*, Vol 21, No. 5, June 1989, pp. 315-337, *Toward Intelligent CAD Systems*, S. Ohsuga. I recommend it to everyone that is studying this topic as a readable and thought provoking summary.

Another related system is Chemilog. This is a logic programming language and system to support the development of chemical knowledge information processing systems. It is an extension of Prolog and is viewed as a constraint logic programming language. In Chemilog, graphs representing chemical structures are treated as basic components and isomorphic graphs and are identified. Constraints such as substructure recognition and replacement of substructures make it possible for users to write programs that handle chemical structures in a visual form. There are two parts, an inference engine and a chemical structure database. Ohsuga emphasizes that while this project is in the domain of chemistry the method can also be applied in other engineering domains where graph representation is used. CHAUS is an extension of Chemilog using KAUS. This was a national project that enlisted the aid of chemists throughout Japan who prepared *knowledge sheets* describing what functionality appears when certain kinds of structural changes in chemical compound are made.

Ohsuga has recently been thinking about applying KAUS to the problem of software design. He claims that an important step in software design is conceptual modeling (rather than formal specifications) and that knowledge processing technology can be fully used in the process of conceptual modeling. Moreover he claims that conceptual models can directly be converted to procedural programs. He is building a system using the meta-level mechanism of KAUS to explore these ideas.

Prof. Hori is involved in the articulation problem. This is the process of cutting a set of symbols out of the nebulous mental world. "I have a concept but I can't verbalize it." It is necessary to articulate this mental world in order to acquire knowledge, model information, etc. Prof. Hori and coworkers have built a system, AA1 for aiding this articulation. Experts often put fragments of ideas consisting of several words and hand-drawn figures on paper, and frequent erasure and rewriting are added when thinking about new ideas. Hori claims that AA1 assists in this stage, and they have experimented with it in the conceptual design of automobiles. Currently they are trying to investigate, from the cognitive science point of view, why the system works so well.

Mainly, Hori's work concerns the bottom-up symbolization process in the human mind. Ohsuga's work is concerned with solving a problem symbolically modeled. Currently, they are trying to connect these two activities. Ohsuga emphasized that he also has interests in human interface, natural language understanding, analogical reasoning, abductive reasoning, nonmonotonic reasoning, learning systems, hypothesis generation, etc., with special emphasis on the world of engineering.

Recent Papers

S. Ohsuga, "How Can Knowledge Based System Solve Large Scale Problems—Model Based Decomposition and Problem Solving," to appear

in *Knowledge Based Systems,* 5(3), 1992.

K. Hori and S. Ohsuga, "Word Space Processor for Assisting the Articulation of the Mental World," in *Information Modelling and Knowledge Bases*, Ohsuga, Kangassalo, Jaakkola, Hori, Yonezaki, eds. (IOS Press, Amsterdam 1992).

Other Papers

S. Ohsuga, "Framework of Knowledge-Based Systems—Multiple meta-level architecture for representing problems and problem-solving processes," in *Knowledge Based Systems,* 3(4), 204-214 (1990).

T. Akutsu, E. Suzuki, S. Ohsuga, "Logic-based Approach to Expert Systems in Chemistry," in *Knowledge Based Systems,* 4(2), 103-116 (1991).

During the JTEC visit to RCAST, Prof. Ohsuga also provided us with a package of preprints from graduate students working in his lab. The titles and authors of these papers are listed below, but for specific information it would be best to contact Ohsuga or Hori directly.

Hiroyuki Yamauchi, "KAUS: Knowledge Acquisition and Utilization System"

Chunye Li, "Problem Model Design/Transformation-Based Program Development"

Ning Zhong, "Knowledge Discover and Management in Integrated Use of Knowledge-Bases and Databases"

Kousuke Yoshizawa, "Soft-Defined Machine" Satoshi Kobayashi, "A Method for Acquiring Problem Decomposition Strategy from Traces" Einoshin Suzuki, "Framework for Connecting Several Knowledge-Based Systems Under a Distributed Environment"

Akira Utsumi, "Primitive Based Representation of Adjectives and Figurative Language Understanding"

Nigel Ward, "Structured Connectionist Studies in Natural Language Processing"

Ionnis Zannos, "Interactive Music Generation System"

Jari Vaario, "Study on the Development of Neural Networks in the Context of Artificial Life"

Shinichiro Yano, "An Approach to Aid Large-Scale Design Problem by Computer"

Y. Minagawa, "The Study to Aid Finite Element Method's Preprocessing with Knowledge Engineering"

Akira Tajima, "Supporting the Development of Intelligent CAD System on KAUS"

Masanori Sugimoto, "A Method to Assist the Acquisition and Expression of Subjective Concepts and Its Application to Design Problems"

Yasunuki Sumi, "A Study of Computer Aided Thinking-Mapping Text-Objects in Metric Spaces"

David K. Kahaner joined the staff of the Office of Naval Research Asian Office as a specialist in scientific computing in November 1989. He obtained his Ph.D. in applied mathematics from Stevens Institute of Technology in 1968. From 1978 until 1989 Dr. Kahaner was a group leader in the Center for Computing and Applied Mathematics at the National Institute of Standards and Technology, formerly the National Bureau of Standards. He was reponsible for scientific software development on both large and small computers. From 1968 until 1979 he was in the Computing Division at Los Alamos National Laboratory. Dr. Kahaner is the author of two books and more than 50 research papers. He also edits a column on scientific applications of computers for the Society of Industrial and Applied Mathematics. His major research interests are in the development of algorithms and associated software. His programs for solution of differential equations, evaluation of integrals, random numbers, and others are used worldwide in many scientific computing laboratories. Dr Kahaner's electronic mail address is: kahaner@xroads.cc.u-tokyo.ac.jp.

HITACHI ACTIVITIES IN AI AND EXPERT SYSTEMS

AI and Expert System activities at Hitachi are reviewed. Current and research projects are mentioned.

David K. Kahaner

In March 1992, a JTEC (Japanese Technical Evaluation Center) team, headed by Prof. Edward Feigenbaum, Stanford University [Email: FEIGENBAUM@SUMEX-AIM.STANFORD.EDU], visited Japan to assess and report on Japanese activities in the areas of expert systems (ES). An oral summary of their report was presented in June 1992 at the NSF in Washington, DC, and the written report will be available soon. The JTEC team visited a large number of laboratories at Universities, government, and industrial R&D centers. I was able to accompany this group on many of their visits. The following report is an overview of one particular research organization, Hitachi, and their specific programs. I have organized this to first catalog some specific examples of expert systems that have been developed by and for Hitachi customers. Thus these illustrate some expert systems that are in use here in Japan. Next we describe major research projects underway that related to the topics of AI and ES and connections to other research around the world.

The main software tool provided by Hitachi is a version of ES/KERNEL. (Separately named versions exist for workstation, mainframes, PCs, and for On-line processing. There is also a new workstation version ES/KERNEL 2 that runs under X-Windows and Motif, which is claimed to be very user friendly.) More than 4,000 copies of ES/KERNEL have been sold in Japan. Source was written in C. Users can make use of various reasoning strategies, including the following:

- Production system: Reasoning proceeds through repetitive sequences of search for selection and execution of applicable rules.
- Object oriented: Reasoning proceeds by repetitive sequences of passing messages to a method within a frame, and method execution.
- Assumption-based: Reasoning starts with a number of possible solutions and solutions that do not meet the specified conditions are discarded. This can be used in the production system as a frame.
- Multilayered: This is a communication mechanism that executes reasoning through cooperation between different expert systems.

Knowledge is represented by a combination of rules and facts — A rule is essentially an IF (condition) THEN (execute something). Facts are either represented as frames or private memos. A frame is used to represent static facts. In ES/KERNEL 2 these are implemented in a hierarchical structure via an object-oriented representation. Private memos represent unstructured knowledge, suitable for the description of transient facts that may be obtained in the course of reasoning.

ES/KERNEL 2 also comes with a graphical knowledge editor as well as a knowledge tailor, which allows knowledge to be moved from one representation to another. In addition, there are two domain shells, ES/Promote/W-Diag, for diagnosis applications and based on ES/KERNEL, and ES/Promote/W-Plan, for planning and scheduling applications that are based on Whispa. (I was told that the next generation of a domain scheduling shell will be based on Tosca, and will incorporate extensive user feedback.) Other packages include a knowledge acquisition tool ES/Tool/W-RI rule induction from examples, a shell for real-time process control, another for plant operation, and a user interface building tool UIBT that has some multimedia capability. There is also ES/Guide for Expert System building support based on the spiral and waterfall model. Unit sales of these other tools are a small percentage of the ES/KERNEL sales. Some fuzzy reasoning has been implemented in this package.

Hitachi has implemented Expert Systems (mostly via ES/KERNEL)

in a large variety of application environments, including the following, which are briefly described. Hitachi points out that "even though the range of application of expert systems is very wide, only advanced firms are engaging in their development, and then in limited areas." Thus, like the United States, smaller companies have not yet embraced this technology. The first list below contains material given to us by Hitachi in very abbreviated form. The second lists the titles and organization of expert systems in use that were provided to us in much more detail (omitted here). Thus, we see that major application areas are in high volume large transaction processing, where the actual reasoning is shallow. Finally, Hitachi pointed out that currently the most important application areas for Expert Systems are for scheduling. Less important, but still significant, are for diagnostics. This is also the case in the United States.

Manufacturing

Blast furnace power generation support—User enters information on the status of turbines or other equipment, and system displays diagnostic messages and results of inferencing.

Melting (steel production) planning support—Optimum stock of raw materials and most economical melting plan is created according to required monthly ingot production volume.

Drainage system construction—User enters size of field and quality of soil, and the system produces design drawings and estimate of expense and time required to complete job.

Resin production planning support — User enters sales data and furnace operating status, and system produces integrated production plan from sales to detailed production process. Knowledge base formed from production conditions and raw material composition.

Boiler breakdown diagnosis—User (repairman) enters details of breakdown, and system produces breakdown cause interactively.

Construction

Shield tunnel planning support—User enters construction period, diameter of bore, route, soil quality, volume of groundwater, and other conditions, and the system determines ideal shape of cutter, number of cutters, and positioning of shield boring machine. This system required about 60 person months to complete and a cost of about US$500K. It contains about 9K lines of C, 100 frames, 850 rules, relates to about 250 parts on a shield machine, and accesses a relational database of about 15K items.

Foundation improvement method selection support—User enters the status of subsidence and the structure to be built, and the system produces optimum foundation improvement method.

Distribution

Work scheduling — Personnel management system for super-markets. Performs inference based on weather, local conditions and Point of Sale data.

Facing (merchandise distribution) control—Creates merchandise distribution (display) and configuration plans.

Dispatch plans—Predicts delivery volume for the day from past data and also displays required number of trucks for each area.

TV channel selection budgeting—Plans for TV commercials are created and budgeting is performed for specific regions.

Government

Oil transformer breakdown diagnosis—User enters type and volume of gas. (Gas contained in a sample of insulation from transformer located in office or building is extracted and analyzed.) Inference is performed to pinpoint cause of trouble and next inspection date is determined.

Landslide diagnosis—Power generation facility sites are checked to see if they are prone to landslides.

Soil nematode diagnosis—Diagnoses whether or not crop damage is caused by nematodes. If so, determines nematode type and displays method to eliminate the problem.

Building inspection—Supports building inspection in areas of design, structure and facilities, to check whether or not they conform to permits and applicable codes.

Elderly welfare consultation—User enters personal data that then judges status and procedures. System also outputs nursing home entrance eligibility.

Securities

Investment portfolio creation support—Sales support system to create investment portfolio for clients from a large variety of products.

Terminal configuration management—Intelligent terminal management for online system. Automates setting of parameters when new terminal is introduced.

Stock investment consultation—Technical analysis of a large number of indices and the experience of stock experts is used to conduct stock consultation.

Insurance

Claims assessment — Judges whether or not claim made by client for hospitalization, etc., should be paid.

New contract assessment—Calculates contract conditions when a new contract is made, based on status of various illnesses.

Health insurance assessment—Supports judgement of amount paid for hospitalization and operations.

Plant fire/explosion risk diagnosis—User enters company and plant name, etc., and risk of fire or explosion is predicted.

Fire prevention diagnosis report generation—Possible risks, foreseeable dangers and improvements are displayed to facilitate creation of fire prevention diagnosis reports.

Finance

Budget assessment—Budget requests from branches for equipment are checked.

Retirement consultation—Calculation of retirement allowance is performed as well as consultation on early payment of retirement.

Optimum plans for land use—User enters location and surrounding environment.

High-return money management plans—User enters return, convertibility and safety issues, system creates asset management plans.

Asset management consultation — Interactive input of client's family and assets is performed. These data are used to make advice on asset management.

Credit check—Checks applications for credit cards for eligibility.

Transportation

Scheduling — Supports creation of schedules for trains and buses.

Operation management — Supports management of train operation.

Computer

Computer breakdown diagnosis—Based on a database of experience from daily maintenance, system judges cause of trouble and instructs repair personnel on proper measures.

Electronic data processing design support—Determines configuration of hardware and software and automatically generates system parameters from estimates of memory and disk capacity.

(Examples of detailed descriptions are available.)

Finance

- Budget Assessment Expert System
  The Dai-Ichi Kangyo Bank, Ltd.
- Design Support System for Financial Planning
  The Dai-Ichi Kangyo Bank, Ltd.
- Expert System for Business Analysis
  Hitachi Credit Corporation
- *Expert System for Inheritance* Advisory Service
  The Nishi-Nippon Bank, Ltd.
- Development Forecast Expert System
  The San-in Godo Bank, Limited
- Pension Consulting Expert System
  The Sanwa Bank, Ltd.
- Private Placement Straight Bond Advice System
  The Sanwa Bank, Ltd.

Insurance

Expert Medical Underwriting System
Daido Mutual Life Insurance Company

Manufacturing

- Defect Diagnosis Expert System for Color Picture Tube *Manufacturing*
  Hitachi Electronic Devices (Singapore) Pte. Ltd.
- Development of a Trouble Diagnostic Expert System for Water Heaters
  Toto Ltd.

Steel/Metal

- AI Applications for Ship Loading Instructions in the Transport Field
  Hokkaido ENICOM Co., Ltd.
- Application of Expert System Assisting Plant Operation in a Steel Mill
  Nippon Steel Corporation, Nagoya Works
- Application of AI to Process Scheduling
  Sanyo Special Steel Co., Ltd.

Distribution

- *Planning Expert System for* Television Spot, Level 2
  Daiko Advertising, Inc.
- Truck Operation Planning Expert Systems
  Nichirei Corporation

Government

Expert Systems for Dissolved Gas Analysis for Power Apparatus Insulating Oil
The Kansai Electric Power Company, Inc.

New Research Areas

Details of research projects were described to us by

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Dr. Motoda was my host on a visit to Hitachi's Advanced Research Lab (ARL), and I reported at that time ["hitachi", 12 Dec 1990] about ARL. Several of the same projects were also presented to JTEC, although at a much later stage of research. There were some new activities too. As readers will discover by perusing the list below, research here is very high class and at an advanced state.

Automatic Knowledge Reformation—Basically this research's goal is to provide tools to make knowledge base-building easier. Specifically, the plan is to automate the generation of an hierarchical, multilevel representation of complex data. The major activity has been to implement a program called Concept Learning from Inference Pattern (CLIP). The major application area is the electric circuit domain. CLIP analyzes the inference process about the behavior of the physical device, and extracts the repetition of the typical inference pattern (i.e., the typical behavior of the device). It generates new abstract level descriptions by replacing the set of descriptions relating to a typical behavior with a single new description. The algorithm is similar to a genetic algorithm in order to avoid exhaustive search. CLIP can restructure a single knowledge base into a more efficient form. It is claimed that inference costs are reduced to one half, or in some cases to less than one tenth. A major remaining research task is to study how to use multiple knowledge bases. (In the circuit case, these could be mechanical, thermodynamical, electromagnetic, etc.) Another research issue is to unify the induction from data with CLIP. I was also told that a second major application domain is solving first order ordinary differential equations, however I have had no opportunity to see this in action.

Discovering characteristic chunks—This research is based on the observation that when we reason, we always think of some "imagistic" chunks relevant to the reasoning process. (Imagistic reasoning is sometimes called visual reasoning.) The goal is to study how and in what situations these imagistic chunks should be acquired and used, thereby hoping to realize sophisticated reasoning in a machine. The domain area is plane geometry. The idea is that experts can recognize a whole figure as a composition of several characteristic figure chunks, giving them a perspective view. The set of chunks will be stored in the knowledge base to be used in solving future problems. The proposed learning theory can be applied to derive these chunks out of the problem-solving process. Plans are to collect a set of these chunks and evaluate quantitatively how much improvement in the reasoning can be gained by using them in solving unseen problems in the future. A related research area is Explanation-based learning (EBL). Hitachi's idea is to use a new concept to address this problem. They call this recognizability, see Masaki Suwa and Hiroshi Motoda, "Learning Abductive Strategies from an Example", Ohio-State Univ Tech Report, 91-JJ-Workshop.

Development of a massive memory workstation—The goal is to explore the architecture necessary to develop a personal computer with gigabytes of memory. It seems that large memory requirements are common in AI applications, and clearly could be of great use in database, CAD, and language processing, among other fields. A prototype workstation has been developed with 64MBytes of memory, using an R3000 (MIPS) CPU, and an Ethernet interface. Current work involves porting Unix as an operating system. There is also work building a nonvolatile read/write 4GB memory machine using an R4000 (MIPS), this also has an Ethernet interface. It is expected that one to two years are required for it to start running. Research plans involve development of a single level storage (integrated memory and file space), precise memory protection (200-500KByte object-wise), and persistency support (incremental execution). In the long run, the plans are to study a new programming model, since it is claimed that current models focus on minimizing code and data size at the expense of execution speed. There is no question that if such a model could be developed to take advantage of huge memory space, it could have a very significant impact on algorithmic development. With memory prices dropping, especially for DRAM, this is an important research direction to follow. Motoda is thinking of the future, when a workbench for intellectual activities will require a terabyte of main memory, and a few tens of gigabytes of memory will be widely available within a few years.

Information processing architecture—The goal is to establish a new framework for an architecture suited to simulate the recognition ability of humans (observation, identification, decision, action, experience, and learning). This is basically theoretical research, but the plans are to experiment with current architectures and extract their problems. The experiments are being done through a small vehicle with information gathering and decision capability in a real environment. The vehicle has two video cameras that feed to an image processing board on a Sun. Data are processed by a software tool kit that then connects with a control data

transducer and is eventually transmitted to the servo motors of the vehicle. The software is built on Motif in object oriented style. The researchers comment that other labs such as MIT, CMU, and Tsukuba have also been working on vehicles for uncontrolled environments. But their main stress has been on the vehicles, whereas Hitachi's research is mainly directed toward a new architecture (hardware and software) suited for mechanization of higher level recognition, using the vehicles only as experimental tools.

Logical interpretation of English sentences—The goal is to perform natural language understanding through the automatic translation of English sentences into logical form. Researchers have made precise the quantification of indefinite noun phrases, and are working on ellipsis, disambiguation, anaphora, plural expressions, etc. It is claimed that their work is an improvement over the Core-Language-Engine developed at SRI.

Formal theory of discourse understanding—The goal is to construct a formal (logical) characterization of discourse semantics. The long term goal is to implement ideas gained here on machine translation or user interface systems, but research so far has concentrated on problems of metonymy. Discourse processing is an active research area, with papers from universities (Stuttgart, Edinburgh, Stanford) as well as government and industry (U.S. Naval Ocean Systems Center and SRI in the United States, and ETL, NTT, NEC, Fujitsu, and Matsushita in Japan).

Formalized programming methods—Researchers have proposed a new programming model (set theoretic programming) and formulated a systematic derivation method of algorithms based on structural induction. Most (not all) textbook algorithms can be derived in this way. Current research is directed toward making this more powerful by using combinations of optimization patterns. Work on formalized programming goes back to E. Dijkstra and B. Nordstrom.

Domain theoretic study of data types with equations—The goals are to develop more expressible programming/specification languages and new semantic theories with more analyzing power. One method, denotational semantics, is a theory based on domain concepts and has been recognized as very useful. The algebraic specification based on equational theories has been thought of as a promising method for formal specification of software. Current research is to clarify the domain theoretic aspects of equationally defined data types. Work in this area is at a very early stage. There is related work at CMU in the United States, Edinburgh in Scotland, and at Pisa and Torino in Italy.

In addition to these projects we were also told that there are activities in

Case Based Reasoning
(Retrieval of reusable cases)
Large Scale Knowledge Integration
(Text based knowledge acquisition)
A New Fast Inference Algorithm
(CREST, Conflict Resolution Strategy oriented matching algorithm)

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY AND THE CHINESE UNIVERSITY OF HONG KONG

Presented is an update on progress at Hong Kong's newest university, Hong Kong University of Science and Technology, and an introduction to the Chinese University of Hong Kong.

by David K. Kahaner

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Several earlier reports on computing in Hong Kong have described the establishment of the brand new university in Hong Kong, the Hong Kong University of Science and Technology (HKUS&T), (Jul 11 1991 hong kong.91, 22 Aug 1991, hong kong.upt, 16 Sep 1991, dattab E-mail: KAHANER@XROADS.CC.U.TOKYO.AC.JP). I did not have an opportunity to visit the new campus until recently (April 1992), at the invitation of

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HKUS&T was incorporated in 1988 and entered its first class of 560 undergraduates and 140 graduate students in October 1991. There are three schools (Science, Engineering, Business & Management) that provide full doctoral programs. Another school (Humanities & Social Science) provides service courses to the undergraduates; it also has its own graduate program. In addition, there are several interdisciplinary Research Institutes and a Technology Transfer Center.

Motivation for a new university came from a sense shared by community leaders that Hong Kong's economic base has been veering away from cheap-labor-dependent industries to more technological industries requiring skilled workers. Cheap labor was a traditional source of Hong Kong's growth, but now manufacturers are moving "off shore." This has led to rapid economic growth by taking advantage of cheap labor in China. A large fraction of Hong Kong's economic growth is currently built on "re-exports," from China on to the West, with rapid increases to Germany and France. Hong Kong's chief industries are still the production of clothing, metals and metal products, textiles, and electronic and plastic products.

Currently, Hong Kong manufacturers employ about 2.5 million people (some estimates are as high as 4 million), but only 750,000 are in Hong Kong. It was realized that the future would require even more bulk manufacturing in China and that Hong Kong needed to provide more of the intellectual product. At the same time, Hong Kong has priced itself out of the competitive pool of traditional manufacturing processes, and it was felt that Hong Kong has not kept pace with technological advancements. Other countries in the region spend far more of their gross domestic product on research; Taiwan and Singapore spend 1.5% to 2.5%; South Korea spends 3%; and Hong Kong spends 0.05%. Earlier

programs led to the establishment of two Polytechnics (Hong Kong Polytechnic and City Polytechnic) in the 1970s and 80s. These institutions provide numbers of technically trained graduates, but the institutions do not perform much basic research.

A shortcoming of Hong Kong's educational system has been that, until recently, only 6% of secondary school graduates went on to the university, compared to about 33% in South Korea and almost 50% in the United States Hong Kong's available tertiary educational system was not large enough to service the demand. The other two universities, Hong Kong University (HKU) (see reports mentioned above) and the Chinese University of Hong Kong (CUHK), are of high quality. HKU is a large, well-rounded institution with a strong computer science department, but with little engineering; CUHK has very strong programs in medicine (see below). HKUS&T is an attempt to add a third public university in Hong Kong built along the lines of a Western model, with outstanding faculty recruited worldwide and focused on enhancing the science and technological base.

The economic situation in Hong Kong is complex. During the past three years, inflation has been high, averaging over 12%. Even with concern about China—or perhaps showing lack of concern—there is still a huge speculation in real estate, with some small apartment values growing 30% to 50% last year. Many experts feel that the main reason for the high inflation is the one-way extension of the manufacturing base into southern China; businesses in China now hold more than US$800M in Hong Kong dollars. Chinese re-exports through Hong Kong go mostly to the West, much less so to other parts of Asia. There has been a large rise of imports from Japan to Hong Kong, resulting in a high trade deficit with Japan. On the other hand, inside Hong Kong, the economy looks strong, with workers taking home 15% to 18% more than in 1991. Hong Kong is and continues to be a trading nation; last year it imported approximately US$200B in goods and services, more than any other country among the industrializing countries of Asia.

Concerning HKUS&T, it is almost unbelievable what has been accomplished in a short period of time. A planning committee did not even exist until late 1986. Today, there are already a campus, faculty, and students in place. The major financial input for the project came from the Hong Kong Jockey Club. Total construction costs are more than $3.6B HK (about US$500M), of which the Jockey Club has contributed almost $2B HK (about US$300-M).

The campus is situated overlooking and extending down to Port Shelter and Clear Water Bay on a portion of Hong Kong that is attached to mainland China in the New Territories region. A bathing beach is part of the campus, and visible islands, as well as most other adjacent land, are restricted to wilderness, park, or recreational use. Campus construction is in keeping with the setting. Buildings are modern and terraced, 130 m up the steep hillside. This is one of the most spectacular university sites that I have seen. University construction is in three phases, radiating out from a central core. Phase one is complete and houses a main administration building, classrooms, laboratories, computer center, library, 400-seat lecture hall, and dorm space for 670 students. This phase consists of over 100,000 m^2 of academic floor space, 1500 rooms, and 50,000 m^2 of additional space. Further residential housing and other laboratory space are being built. Phase two provides support for 5000 students and includes the majority of the sophisticated lab space; this is to be completed by the end of 1992. Plans are to have 7000 students enrolled by 1996 and room to expand to 10,000 students, 1000 faculty, and 2000 support staff.

The vice-chancellor and president is Chia-Wei Woo, who was recruited away from his position as president and professor of physics at San Francisco State University. The university's first pro-vice chancellor and also professor of physics is Chih-Yung Chien, from Johns Hopkins University, who has now decided to return to teaching and research in the Physics Department; his successor is Shain-dow Dung, former professor of botany and provost of the University of Maryland's Biotechnology Institute. Their stated view is that a research university is either world-class or nothing and that the new university would be world-class in 10 to 15 years. "When you start a university, you want to appoint senior people who, in turn, will recruit junior colleagues. The deans, the department heads, the senior professors, all have to be absolutely world-class." For example, Stelson was executive vice-president of Georgia Institute of Technology. He was also an assistant secretary of energy during the Carter administration. The computer science chairman, Shen, has his Ph.D. degree from Princeton (EE). He was recruited from the Microelectronics and Computer Technology Corporation and has a background in software engineering.

Many of the other senior staff members have similar credentials, although almost all have some ethnic association with China. (Stelson does not; he has a five-year contract.) In the Computer Science Department, there are about a dozen lecturers, most with Ph.D. degrees received within the last five years from well-

known universities. Shen explained that 12 more faculty are expected by next fall, and he plans to have 50 persons on the academic staff by 1994. Rapid growth has been the norm all over the campus. Plans are to recruit 100 faculty a year through the 1990s.

I was shown a number of plans for research projects that HKUS&T faculty/staff are involved in. However, first priority is simply getting organized. Hallways are cluttered with boxes hastily being unpacked and moved into waiting laboratories; senior faculty are so busy with recruiting that they are often on travel; new faculty are looking around for basic information; and construction people are everywhere. The energy level is very high. Since so many of the faculty come from excellent research universities in the West, it is natural that they will come with research projects and ideas they want to develop. But new projects must reflect the needs and strengths in Hong Kong. The Research Center gives a good indication of these directions; it has identified four major areas:

Environmental research and development of technologies to improve environmental quality in Hong Kong. These projects relate to air, water, and waste pollution, databanks for ecosystem, river sediment research, etc.

Energy research. These projects relate to the need to deal with Hong Kong's electrical needs, which are doubling every six years. Projects involve boundary-layer wind-tunnel studies, flue-gas desulphurization, power plant automation, seawater scrubbing, electric vehicles, eletromagnetic field impact on humans, revegitation of fly ash-lagoons, etc.

Infrastructure. This relates to the Hong Kong government's plans to spend billions (U.S.) on transportation improvements. Projects, not yet specified, will be in the areas of civil and mechanical engineering.

Database development. Relates to the need to establish a database of scientific and technical data.

These are all just beginning, with the environmental program somewhat better developed. Most projects are in the phase of setting up agreements with other organizations, selecting directors, etc. For example, there are discussions with the Chinese (PRC) Institute of Oceanography to conduct joint sediment research in the Pearl River delta and in Hong Kong, with the Chinese providing the ocean-going vessels. Similarly, there are discussions with the Jet Propulsion Lab for participating in the satellite remote sensing of the sea environment and for establishing a ground receiving station for high resolution data. The projects that have been detailed are mostly small. The largest, the development of a large boundary layer wind tunnel and related modeling for pollutant dispersion, is budgeted at HK$16M (US$2.2M).

There are already a small number of funded research projects, mostly in the Engineering School and funded by the Hong Kong government. These total about US$15M for three years. One project that looks very interesting is the development of an application specific integrated circuits production line to be built jointly with a U.S. company. There is also the expectation that a 2-3μ semiconductor fabrication facility will be running by fall 1992; it will be used for testing and teaching purposes.

Stelson asks, "What kind of research does Hong Kong need? For answers, one need only look at government's and industry's plans for the territory's future. The government spends HK$2 to 4B (US$300 to 600M) yearly on environment-related tasks and has promised to build a HK$20B (US$3B) sewage system to clean up Victoria Harbor. Within the next five years, the China Light & Power Company will build one of the world's largest fossil-fuel power plants, with a capacity of more than 6000 MW at an estimated cost of HK$60B (US$9B). A nuclear power plant will be switched on in China at nearby Daya Bay. And Hong Kong will spend an estimated HK$127B (US$18B) to build a new airport and expand what is already the world's busiest port."

There are also interdisciplinary research institutes. The first, a Biotechnology Research Institute, was established in 1990 with a HK$130M (US$20M) grant from the Jockey Club. Eventually this will support 50 university staff from 10 departments. There is a second cooperating Institute at the Chinese University of Hong Kong, the Institute for Information Technology was established at the end of 1990 with a HK$100M (US$14M) grant from Hong Kong Telecommunications. (Telecommunications is big business in Hong Kong; one person in 10 has a pager, one in 30 has a mobile phone, and there are 30,000 T1 equivalents.)

The Computer Science Department has identified four major research areas that they will focus attention on, all related to software.

Artificial intelligence
Computer engineering
Data and knowledge management
Software engineering

The university is networked with a fiber distributed data interface

(FDDI) backbone, modeled after the Project Athena in the United States.

Most of the projects are just beginning, but there are interesting developments almost daily. For example, The Computer Science Department has received a HK$20M (almost US$3M) donation to establish a Software Engineering Research Center, and a search is on for a director. The center will support both academic and commercial activities related to software engineering. For example, faculty are developing a Chinese X-terminal system that can accept different Chinese input systems, potentially very useful in this part of the world. The center also plans to let a contract for commercial development of information retrieval technology developed at the university; they will use income from the license to supplement the donation.

The Computer Science Department is clearly focusing its energies in different directions than traditional scientific computing, mathematical modeling, numerical analysis, etc. Professor Shen pointed out that these subjects are considered within the scope of the Mathematics Department, which is headed by Professor Din-Yu Hsieh (recruited from Brown) and a couple of people now in mathematics work in these fields, but I have no further details at this time. Shen also explained that several of the new computer science faculty are interested in parallel and distributed computing. During my visit, Professor Nelson Cue, who heads the Physics Department, asked me about various computing possibilities, suggesting that his department was hoping to obtain sufficient computing resources to deal with their own needs. The university has several HP9000s donated by Hewlett-Packard and is discussing the possibility of a small supercomputer with DEC. However, it is unlikely that any action will be taken before more specialists arrive, as the general philosophy is not to buy computing equipment before there is a faculty member committed to using it. (Wise decision.) Several years ago, an international panel investigated the possibility of a supercomputer for Hong Kong. Their conclusions were that this was not justified at the time. Perhaps the situation has now changed with the opening of HKUS&T. Engineering problems are greedy users of floating-point computing cycles. Further, I cannot think of many first-class scientific universities in the West that do not have advanced computing capability readily available, as well as internal expertise and research in scientific computation.

HKUS&T uses English as its teaching language. This decision is an excellent way of assuring that the university is a hospitable place for visitors and that technical information can easily flow both in and out. It certainly makes sense in the short run. But not all students are sufficiently prepared. I asked Professor F.H. Lochovsky who, with his wife, teaches in the Computer Science Department, about the quality of their students. He commented that often their progress seems mostly related to their skill in English and perhaps less to their ability or work habits. There are various remedial programs, but in the long run, I wonder if this will be an impediment or a benefit to getting the quality of research and scholarship that the university desires. It is also not clear to me if China will encourage movement to the Chinese language as the university becomes more established.

Of course China is the one, huge unknown in the future of Hong Kong—that is, the effect that Hong Kong's reversion to China in 1997 will have. There seem to be as many opinions on that as there were people that I spoke with. For the most part though, the university staff seem to feel that nothing much will happen, at least for a while. More generally, while many Hong Kong citizens are attempting to get passports from other countries, a British program to offer full British passports to selected citizens has been significantly undersubscribed. For those of means, Hong Kong's maximum 15% personal income tax rate is very appealing.

During my visit to HKUS&T, I was asked to give a briefing to the university faculty about the Office of Naval Research and especially on the role of our office in Tokyo. This was followed by a talk by my colleague, Dr. Iqbal Ahmad, who gave a similar explanation about the U.S. Army's Asian Research Office. This was the easiest briefing I have presented in this part of the world, because essentially 100% of the audience already had some experience with U.S. basic research funding agencies, including both ONR and ARO. This would make the chemistry of collaborating with U.S. science organizations and individuals extremely easy. It is also clear that the university administration is anxious for collaborations. While it is still too early to see how projects will turn out or whether HKUS&T will really turn into a world-class institution, the quality of the faculty suggests that Western researchers can go there and feel that they will get equal measure to what they contribute.

THE CHINESE UNIVERSITY OF HONG KONG

I have not yet been able to visit CUHK, but

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was gracious enough to send me a copy of the university's summary of research projects for 1989-90 (the 1991 edition was scheduled to be ready in June 1992). The summary provides a comprehensive list of research activities. An introductory note from the vice-chancellor, Dr. Charles K. Kao, lists as the first goal for the 1990s, as "increasing linkages with academic institutions worldwide with substantial exchanges, research program and training opportunities."

CUHK is a large university, but it has an emphasis on medicine; fully one third of the research projects are from that faculty, with mathematics, computer science, electrical engineering, and information engineering accounting for less than 10%. There are no other engineering programs. Below we list the titles of research projects from these four departments.

Mathematics:

- Soliton Equations with Variable Coefficients
- Controllability and Stability of Nonlinear Distributed Parameter System
- Variational Theory for Fully Nonlinear Elliptic Equations.
- The Geometry and Analysis of Pseudoconvex Cauchy Riemann Manifolds
- Ring Theory, Semigroups, and their Applications—Research in Cliffordian Semigroups and a book on rings with chain conditions
- Harmonic Functions on Manifolds; Surfaces of Constant Mean Curvature
- Standard Split Inclusion on Von Neumann Algebras
- Book on theory of ordered convex spaces and operators

Computer Science:

- Automatic Input System Using Connectionist Models
- Invariant Object Recognition Using Connectionist Models
- An Intelligent Graphic User Interface for Computer-assisted Learning in a Computer Library
- Globally Convergent Interative Finding of Zeros of Polynomials
- Computer Processing of the Chinese Language
- Graph Theoretical Approach to Computer Optimization
- Numerical Solutions of Integral Equations
- A Pattern Recognition System Using Probabilistic Logic Neuron Nets
- Robotic Vision System Using Logic Neurons
- Logic Program Debugging
- Algorithm Animation
- An Expert Computer System on Medical Consultation and Management
- A Specification-based Neural Network Simulation Environment
- Machine Translation
- On-line Recognition of Hand-written Chinese Characters
- Font Design of Chinese Characters
- Multimedia Information System with Voice Input
- Linking Home Audio/Visual Equipment to Personal Computers
- Parallel Ray Tracing Algorithms
- Social Issues of Information Technology in Hong Kong
- Computer-aided Fashion Design
- Computer Stereo Vision and the Automatic Navigation of Robot
- Computer Speech Synthesis
- Temporal Database
- Project Scheduling
- Semantic Database

Electronic Engineering:

- Analysis of Error Behavior in the Implementation of the Integer Cosine Transform
- Weighted Cosine Transform
- JPEG Coding Algorithm
- Adaptive Filtering
- Secured Speech Radio System for Paramilitary Applications
- Man-machine Communication by Voice
- An Auto-synthesis Design System for a Low Power Bipolar Logic in VLSI Applications
- Application of Expert System on Gate Array Selection
- BiCMOS Implementation of UAA 4802 PLL/Prescaler
- Placement Algorithm for Incremental Layout Alternation
- Digital Pulse Width Modulator Converter
- Impedance Pneumography
- Radial Pulsewave Technique
- Electric Wheelchair
- Instrumentation and Signal Processing in Biomedical Engineering
- Investigation of Novel Fiber and Integrated Optical Devices for Fiber Communication Systems
- Epitaxial Growth of III-V Compound Semiconductor Materials

- Comparison of Standard G3 Transmission and ECM G3 Transmission
- ISDN Development and Trials
- Semiconductor Laser Research
- The Growth of Kinetics of Ordering
- Deep Level Transient Spectroscopy of Implanted Semiconductors
- Buried Nitride by Ion Implantation
- Effects of Damage on Impurity Diffusion in Silicon
- Spectroscopic Ellipsometry
- Pixel Relaxation Labeling
- 3-D Object Recognition Using Rigid Body Model
- Convergence Study of Neural Network Training
- A Class of Median-Based Multishell Filters
- A Real-time Nonlinear Video Image Processor
- Microstrip Antennas and Arrays on Curved Surfaces
- Bandwidth Enhancement of Microstrip Antennas
- High Frequency Electromagnetic Wave Propagation and Scattering by Gaussian Beam Wave Theory
- Integrated Optical Devices
- Research in Optoelectronics Device Technology
- 3-D Imaging by Structured Lighting
- Multiresolution Edge Detection and Surface Contour Detection
- A Real-time Machine Vision System
- Object Recognition by Matching Edges and Vertices
- Characterization and Effects of Implantation in Semiconductors
- Ion Implantation of Advanced Thin Film Materials

Information Engineering:

- Hand-written Chinese Characters Recognition Using Neural Nets
- Information Technology Related to Chinese Language
- An Enhancement of the Alternating Projection Neural Networks (APNN) with Fuzzy Sets
- Exploration of the Functional Link Nets' Architecture
- Adaptive Filtering
- Fuzzy Neural Nets
- Simulations of Designs
- Broadband ATM Switches
- Searching for New Barker Codes and Other Codes with Similar Correlation Functions
- Interactive Computing in Engineering Design
- Design of Controllers for Linear Parameter-varying Systems by the Gain Scheduling Technique
- The Nonuniform Compact-pattern Channel Allocation Algorithm for Cellular Mobile Systems
- Hierarchical Distribution of Video with Dynamic Port Allocation

CONFERENCE

The upcoming conference listed below might be of interest to readers.

Second International Computer Science Conference (ISCS'92) Data and Knowledge Engineering: Theory and Applications, Hong Kong, 13-16 Dec. 1992

Information:
Dr. Earnest Lam
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CHULALONGKORN UNIVERSITY ASIAN INSTITUTE OF TECHNOLOGY, NATIONAL ELECTRONICS AND COMPUTER TECHNOLOGY CENTER, Thailand

Visits to three Thai research institutes are reported. While basic research is not at U.S. levels, Thai scientists are anxious to collaborate. Asian Institute of Technology is unusual in that all instruction is in English, it is supported internationally, and its mission is to serve Asia.

by David K. Kahaner

Scientists from the West will not be surprised to discover that the level of computing research in Thailand is much lower than in the West, in Japan, and even in Korea, Hong Kong, Singapore, and Taiwan. This includes computer science research as well as utilization of advanced computing facilities for other science and engineering computation.

The country has many economic and infrastructure problems that take precedence over basic research. However, many Thai scientists have been trained in the West and return to their home with good contacts and are well versed in current technology. In addition, Thailand hosts many scientists from much poorer countries such as Viet Nam who are highly motivated to succeed. The country has had very spectacular economic growth, largely because of the low cost of labor, thus making it the manufacturing center for other countries. One Western factory manager I spoke to explained that basic factory wages are one tenth or less of those in the West. However, real costs are much higher because of inefficiencies and unusual expenses necessary to do business there. (Some of Thailand's business practices have led to being cited as being restrictive to U.S. commerce, especially regarding intellectual property protection.) There are plenty of Western companies in Thailand, but it is not clear to what extent they are engaged in technology transfer or just in manufacturing operations. The key to maintaining economic growth is to educate the population and provide the type of intellectual infrastructure that allows Thai business to add value to labor. For example, the Ministry of Science, Technology, and Energy has provided almost 700M Baht (about US$55M) to build a large science museum in a province just north of Bangkok. The Ministry claims that this will be world class, and that it will attract a half million visitors each year. The project is being developed by the Thailand Institute of Science and Technology Research (TISTR) and will open in 1994. (This is hoped to be the anchor of a technology center.)

The largest business in Thailand is the Petroleum Authority of Thailand (PTT), which has annual revenues of more than 100B Baht. This is a state enterprise that the state is trying to streamline operations along the lines of a private company. PTT's original structure of power centralization, work duplication, and many rigid regulations (similar to those of other Thai government agencies) has been dismantled, although PTT is still a government agency in the sense that it observes government policy.

The Thai government is prepared to spend billions of dollars U.S. in developing and improving the infrastructure to make it adequate for the tremendous expansion that they have been experiencing. Thailand is building new roads, railroads, ports, and telecommunications systems as well as expanding its electricity grid. One U.S. diplomat commented that the national bird of Thailand is the construction crane.

The problem for the research community, even those who have good Western connections, is that it

is difficult to continue their research because of lack of facilities and heavy demands on their time. In addition, keeping in touch with activities far away is taxing. At least one university that we visited, the Asian Institute of Technology (AIT) had some electronic mail access. However, it is routed through Australia on a slow and expensive telephone line. Mail messages larger than a few thousand bytes are discouraged, and large messages will not be delivered. One major project of the National Electronics and Computer Technology Center (NECTEC) (below) is to improve this situation. Fax is heavily used. Communications infrastructure is seen as a key factor in technical progress during the 1990s.

More generally, information technology (IT), is viewed as a tremendous potential for giving not only Thailand, but many other developing countries in the region, an important step up. Governments in these countries are aware that they produce much of the hardware used in the small computer market; see Table 1.

However, most of the software is produced elsewhere; this is one area that these countries are determined to change.

Table 1 — Asian IT Production

Hardware	Totals	Percent of world prod.
PCs	7.2M	30%
Monitors	23.0M	90%
Hard Disks	15.5M	85
Dot Printers	11.3M	8

Very little is unique to Thailand in this context. The Thais are active participants in regional forums and have their own computer association as do all the other countries.

Computer Association of
Thailand (CAT)
Mr Thavisakdi
Thangsuphanich, Director
28/18-21 Sukhumvit 19, Bangkok
10110 Thailand
Tel: +66 2-215-3546,
Fax: +66 2-215-3962

For example, SITO, the Southeast Asia Information Technology Organization, which is headquarterd in Taipei, Taiwan ROC (founded in 1988) is a nonprofit, nonpolitical organization .devoted to promote and develop IT within the region. SITO publishes a free newsletter, "SITO Review" that surveys activities and lists meetings of interest. Circulation is about 10,000, although SITO's primary interests are not in basic research. For copies or further information contact:

SITO Secretariat
3F, No.2 Pa-teh Road, Sec 3
Taipei Taiwan ROC
Tel: +886 2-776-4249,
Fax: +886 2-776-4410

An even more business oriented regional publication, although still sometimes containing useful pointers or columns is:

"Asia Computer Weekly"
100 Beach Road, #26-00
Shaw Towers, Singapore 0718

Of course, many exhibitions that include some technical sessions are held. I have listed a few of the shows in Table 2 to let the readers get a sense of the region's activity.

CHULALONGKORN UNIVERSITY (BANGKOK)

Pronounced Chu/la/lon/korn, this is the oldest and best known university in Thailand. Founded in 1917 on 500 acres in central Bangkok, in honor of Thailand's King Rama V (King Chulalongkorn), who is credited with developing a modern educational system in the country. (When Thailand was known as Siam, education was for males only and was taught in the Buddhist monasteries.) There is still a close and warm connection between the university and the Thai Royal Family. Thai people are unreservedly royalists.

"Chula" is a large university, with a faculty of almost 2,500 and 85,000 graduates. Of course, the university's main activity is to educate; however, it also engages in substantial research activities. There are seven research institutes, including Biotechnology, Genetic Engineering, and Metal and Material Science. Also, special pooled research groups (called cells) center around laboratories, such as:

- Semiconductor Device Research Lab (SDRL see below),
- Semiconductor Design Lab,
- High Voltage Lab Computer,
- Chemistry Lab,
- Neuroscience Lab.

The University tries to have an international outlook with various exchange agreements, conferences, and collaborations, although these are highly focused on basic needs, such as health, energy, and population issues. Similarly, there are special area of studies that aim at increasing cultural awareness (American-Canadian Studies, Asian Studies, and Perspectives on Thailand.) A special Technical Cooperation with Neighboring Countries

Table 2 — List of Technical Exhibitions Held inthe Asisn Region

Country	Exhibitions	Date
Hong Kong	COMPUTERS'92	5/12-15
	CENIT Asia '92	9/92
	HK International Electronic Fair	10/14-17
India		
New Delhi	CONDUIT'92	5/92
New Delhi	Electronics India '92	9/92
New Delhi	MAIT'92	9/92
New Delhi	INDIA COMM'92	10/13-16
Indonesia, Jakarta	Microcomputing ASIA '92	6/12-16
Japan, Yokohama	Supercomputing Japan '92	4/22-24
Tokyo	Int'l. Business Show	5/20-23
Tokyo	'92 JPSA Show	6/9-12
Makuhari	Networld Japan '92/Soft World '92	7/21-23
Makuhari	Japan Electronics Show '92	10/13-17
Tokyo	COMNET/Tokyo'92	12/19-21
Korea, Seoul	KIECO'92	4/15-21
Seoul	PC SHOW '92	9/4-8
Seoul	CAD/CAM'92	9/92
Seoul	CN KOREA'92	12/4-7
Mainland China (PRC)		
Shenzhen	ELECTRONICS CHINA '92	10/19-23
Beijing	MLIPOA'92	10/26-30
Beijing	EXPO COMM CHINA '92	11/4-9
Malaysia		
Kuala Lumpur	SEARCC & SRIG-ET	8/11-14
Kuala Lumpur	PIC '92 — PIKOM 2nd Industry Conf.	11/16-18
Kuala Lumpur	PIKOM Fringe Event Series #1	11/16-22
Kuala Lumpur	ITX '92 — 4th Intl. IT Expo.	11/19-22
Philippines, Manila	Electronics Asia '92	6/92
Manila	PHIL TELECOM '92	8/26-28
Manila	COMDDAP Show	10/6-9
Singapore	CommunicAsia'92	6/2-5
	InfoTechAsia'92	6/2-5
	The PC Show '92	6/25-28
	COMTEC'92	9/10-13
	EXEX ASIA '92	9/23-26
	INFORMATICS '92	10/15-18
SITO Secretariat	Annual Conf & General Assembly	11/16-20
Las Vegas	Comdex/Fall '92	
Taiwan, Taipei	SOFTEX Taipei '92	5/7-10
Taipei	COMPUTEX Taipei '92	6/5-9
Taipei	Taipei Computer Applications Show	8/15-19
Taipei	Taipei Electronics Show	10/7-13
Thailand, Bangkok	Thailand IT Week '92	9/92
Bangkok	INFOMATIC & TELEMATIC '92	9/10-13
Bangkok	Computer '92 Communications	10/1-4

program (TCNC) focuses on interregional cooperation. A student exchange program that initiated recently with the University of Oregon allowed a half dozen U.S. and Thai students to be exchanged. University administrators are enthusiastic about the growth of international programs; the Director and Deputy Director of the International Affairs office obtained graduate degrees in France and the United States, respectively. Also, two English-based graduate programs in business (MBA) and in management (MM) are located at the Sasin Graduate Institute of Business Administration within the university. The Sasin Institute is a joint program with faculty from Northwestern University's Kellogg School, and the Wharton School at the University of Pennsylvania.

Our hosts at Chulalongkorn were

Prof A.Techagumpuch,
Physics Department
Chulalongkorn University
Bangkok 10330 Thailand

and

Prof Somchai Thayarnyong,
Department of Computer Engineering
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Semiconductor Device Research Lab (SDRL) (Chulalongkorn Univ.)

This laboratory began in the mid 1970s with capital equipment donated by the French government. The equipment included diffusion furnaces and vacuum evaporator. It was the first semiconductor laboratory in the country, and its early work was directed towards the fabrication and application of solar cells as well as research on planar silicon techniques. The current staff of about one dozen people includes eight researchers and has added equipment such as gas purifiers, 4-point probe, ultrasonic cleaner, laser system, liquid phase epitaxital furnace for GaAs, molecular beam epitaxy for quantum well devices, scanning electron microscope, automated electrical device characterization system, photoluminescence measurement system, cryogenic system, and electron beam evaporator system. Support for the Center, over the years, totals almost 62M Baht, about US$5M. Of this, the largest single grant was for 25M Baht, in 1992, from the Japan International Cooperation Agency (JICA) for the purchase of a RIBER molecular beam epitaxy machine and accessories. Much smaller grants were also made by the Hitachi Scholarship Foundation, Stiftung Volkswagenwerk Foundation, and the Toray Foundation. Current work in the center includes laser technology, compound semiconductor, photovoltaic system, optoelectronics, and multiquantum well devices. A one kW system was designed and fabricated for use for 24-hour lighting for plankton cultivation. Research is in progress in the area of polysilicon solar cells and GaAs/GaAlAs heterojunctions. In addition to conducting research, SDRL is also supporting projects of five to seven undergraduates and some master's students. In 1985 a Ph.D. program, in EE was approved for the university. Several students associated with the Center have received masters degrees; some others are in the Ph.D. program, but as yet no degrees have been awarded.

Accompanying me on this visit to Thailand was Dr. Iqbal Ahmad, of the U.S. Army Asian Research Office. Ahmad agreed with me that we saw very little in the way of state-of-the-art or world-class research at Chulalongkorn. The SDRL is well established and provides excellent links to industry. It is also beginning to do Ph.D. level work. In my opinion, with which Dr. Ahmad concurs, this laboratory is capable of being a useful partner to Western researchers and would provide a good long-term investment. The Director, Prof. Somsak Panyaeow expressed a desire to work closely with U.S. scientists. At this time his interactions are mainly with Japan and France.

The VLSI Design Lab was meagerly equipped and doing only the most basic design and simulation work. There are 12 IC assembly plants, but no fabrication facilities in Thailand. The main task of this and other labs is currently to train undergraduate and a few masters students. This does not permit venturing into many areas of advanced research. For example, in the semiconductor lab, I explained to one faculty member about the Mosis prototype fabrication project in the United States; he was totally unaware of this. We saw no computer science research of significant depth. Electronic mail communication with the West does not appear to be available yet.

NATIONAL ELECTRONICS AND COMPUTER TECHNOLOGY CENTER (NECTEC)

At NECTEC we visited

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NECTEC is the Thai government organization charged with upgrading the country's research and development capability in electronics and computer technologies as well as accelerating computerization of Thai society. This is quite consistent with my earlier comments that IT is seen as an important growth area and that Thailand cannot rely of the exploitation of cheap labor to fuel societal improvements for much longer. NECTEC's current budget is in excess of 60M Baht (about US$5M) and is used to fund activities in twelve major program areas.

* Subfractional horsepower motors for electrical appliances
* Artificial intelligence
* Computer networking
* VLSI design and fabrication
* Biomedical electronics and instrumentation
* Materials and devices technology
* Industrial electronics and instrumentation
* Computer system technology
* Computer software development
* Telecommunication equipment
* CAD/CAM
* Technology transfer and training

NECTEC funds R&D work as well as product development. It tries to encourage joint projects involving university scientists and state-run institutes, private companies, and representatives of MOSTE, e.g., NECTEC.

Although the organization was set up in 1987, it does not yet have its own lab. Dr Pairash (Thais prefer to be addressed by using their given name) told me that he expects a lab to be set up soon, and plans to have about 60 engineers within two years. Several projects have been completed however. Two computer related projects that I was told about were a Thai-speaking clock and a CAI package. An active research and development effort involves making X to 25 connections to a dozen Thai universities and then to the Internet. Printed circuit board assembly also exists at the local Century Electronics System Co—not earth-shaking, but a small, step toward developing internal expertise. Thai software houses are very small, and skills are weak. For example, an effort to develop software for tax computation had to be contracted out to a Danish company. On the other hand, a local effort was successful at developing a Thai-language computer character set for display on PC screens.

The best way to improve local skills is by cooperating with others; a view that is supported by NECTEC. There are two current international NECTEC projects.

ASEAN-Australia Microelectronics (1986-1992), which resulted in an 8-bit counter and a decoder. Other countries involved in this are Brunei, Indonesia, Malaysia, Philippines, and Singapore.

Machine translation system for Japan and Neighboring Countries Project (1987-1992). This is coordinated by the Japanese Center of International Cooperation for Computerization (CICC), which is working on machine independent software packages for translation of languages in participating countries, i.e., China, Indonesia, Malaysia, Japan, and Thailand. CICC also has other training-related programs; for example, one that provides training courses in computer system software technology. The courses are held in Japan. All travel and living expenses are borne by CICC.

NECTEC's new projects are focused on hardware development, software development, and legal and information management. There will also be a program to provide services to inspect standards for electronics and computer products in order to help promote export of these items. In the past, many Thai electronic/computer products have failed to pass importers inspection. One aspect of the information management project involves studying details of foreign laws on technology to help the Thai private sector in avoiding conflicts over copyright issues regarding software.

NECTEC also supports a CAD Center that has several popular Western software products, including Auto Cad, Orcad, Mould Flow, Mentor Graphic, and Unigraphic II. The Center has three HP9000 Unix workstations available, about a dozen HP Vectra ES, and a similar number of Tavon (386 SX) PCs.

While at NECTEC we were told about two other technology Centers, but did not see either one. The National Center for Metals and Materials Technology (NCMM), and the National Center for Genetic Engineering and Biotechnology (NCGEB). NCGEB is focused on agricultural (land and marine) applications as well as public health. NCMM promotes research in metals as well as in ceramics, polymers, fibers, textiles, and rubber. In these, as well as all NECTEC's projects, there is a strong commitment toward international and bilateral cooperation, especially with advanced Western countries. We were specifically told about agreements between Thailand and Germany, Australia, United Kingdom, and the United States.

There are also agreements with international organizations, including several sponsored by the United Nations.

All of these programs are still in either the development stage or providing very early results. It will take a number of years before a significant research tradition is established, and even then the major emphasis will remain on development, improvement, and standardization.

ASIAN INSTITUTE OF TECHNOLOGY (AIT), BANGKOK

AIT was founded in 1959 as the South East Asia Technology Organization (SEATO) Graduate School of Engineering, to provide graduate-level civil and hydraulic engineering education not only in Thailand, but in southeast Asia generally. Ten years later it was restructured into an international institution focusing on regional problems and their engineering, scientific, and management solutions. In 1989 AIT received the Ramon Magsaysay Award for International Understanding "in recognition of its shaping a new generation of engineers and managers committed to Asia, in an atmosphere of academic excellence and regional camaraderie." A list of AIT's basic programs (in some cases leading to Ph.D. degree) gives a clear sense of AIT's mission.

- Agricultural engineering, food engineering, land and water development (this is the largest program),
- Computer science,
- Environmental engineering,
- Energy technology,
- Geotechnical and transportation engineering,
- Human settlements development,
- Industrial engineering and management,
- Natural resources development and management,
- Structural engineering and construction,
- Telecommunications, and
- Water resources engineering.

In addition to these programs there are a number of outreach programs, such as in-service training, short courses, summer courses, etc., and a regional documentation center. AIT was the one location in Thailand where the staff had electronic mail, although as mentioned above it is not fully satisfactory.

AIT's campus is 400 acres large, about 30 miles north of Bangkok. (I was told that the Thai government has hopes of establishing an adjacent technical park.) Currently there are about 800 students (20% women) mostly from Asia plus 200 faculty and staff. Almost half the faculty are seconded from other institutions by countries that support AIT. In 1989, faculty and staff secondments totalled more than 70 person-years, broken down as follows:

Australia (person-months)	24
Canada	61
China PRC	6
China ROC	7
Finland	10
India	27
Japan	136
Korea	23
Norway	22
Sweden	2
Switzerland	22
USA	18
EC	468
Commission	12
Belgium	27.5
Denmark	32
France	146
Germany	132
Italy	4.5
Netherlands	24
UK	90
	855

It is clear that a very significant fraction of the faculty are not Thai. I was surprised to learn that several of the faculty are Vietnamese, and in fact Prof. Kanchana (CS) felt that some of her best students were often from Viet Nam or India (approximately 60 students are from each of these countries). The campus is very attractively landscaped and includes enough dormitories and houses to accommodate most of the staff and students. There is a nine-hole golf course, and naturally a cricket field, among other things. Over the years AIT's 5,500 graduates have come from 35 countries, with the largest groups (1961-1990) as follows:

Thailand	1306
Taiwan ROC	647
Philippines	560
Sri Lanka	409
Bangladesh	358

Financial support for AIT is as follows:

Governments (22)	76%
International organizations (30)	5%
National government agencies (20)	6%
Business, foundations, private, (18)	13%

In FY 1989-90 AIT received almost 440M Baht (about US$35M). A significant fraction of this went to support new programs, especially a new Telecommunications Division (see below), which accounted for almost US$5M, including 26M Baht from the government of Finland for the construction of a telecommunications building. (The 1990 grants for continuing education were 57M Baht, about US$4.5M.) There is a very substantial mix of grantors. United States organizations were heavy donors in the past (we were shown

several large buildings that were said to have been construc-ted with U.S. grants). The U.S. government still accounts for 4.5% of AIT's cash contributions, although several other U.S. institutions and universities increase this slightly, but current large donors include Japan, Canada, and Finland. For an institution serving the needs of Asia, costs are surprisingly high; student expenses including tuition, fees, and living expenses are estimated to be over $4,100 per trimester, i.e., over US$12,000 per year. Presumably, most of AITs students are supported by either their host government or other kinds of financial aid; only about one quarter of the students are self supporting. With such a diverse student mix, it is not surprising that English is the AIT language for instruction, documents, and service. Western visitors will feel very comfortable here, and in fact the entire senior administrative staff from President to Academic Secretary are Western.

In support of the educational program are laboratories and research centers, including the following:

- Environmental engineering laboratories,
- Regional computer center,
- Remote sensing laboratory,
- Computer integrated manufacturing laboratory,
- Telecommunications laboratory,
- Regional research, development and experimental center for projects in agricultural, food engineering, and water resources.

The computer center has an IBM 3083 with about 150 terminals and PCs. There are also some CAD workstations, image processing workstations for processing satellite-sensing data, and a microwave data transfer facility. There are also stand alone PCs (IBM and NEC) and others that are on a LAN. There is a variety of software, including a very impressive suite of scientific software from IMSL, NAG, SAS, and SPSS. The Computer Science Department has about 50 additional micro/mini computers from a potpourri of companies—Apple, IBM, Fujitsu, NEC, APC, Philips, Sun, Sony, and Norsk.

Our hosts at AIT were

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and

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In the CS Division, specialization is in software engineering, AI, and information technology. But there is not much time for research, and the permanent staff that arrives is well trained from good universities in Japan, Germany, Australia, United States, United Kingdom and other places and is concerned about falling behind. The research program here does not look as strong as in some of the engineering divisions and is rather theoretical. For example, Prof. Kanchana specializes in discrete algorithm analysis. In 1990, 12 journal papers were published and four contracts (expert systems, Thai sentence analyser, logic programming, and inventory system). One exception is Prof. Huynh Ngoc Phien [HNP@AIT.TH] who states that his interests are in mathematical software, computer modelling, simulation, statistics, and geometry; although I was not shown any of his work. I only learned about one collaborative activity between CS and faculty in an engineering program. Given AIT's heavy emphasis on engineering and its concurrent computer needs, there are tremendous opportunities for joint research. For example, many students study structural engineering that has heavy computational demands. Similarly, the Division of Water Resources Engineering has significant needs not only in modelling but in database design and utilization. At present, computational courses are offered in specialty departments, such as "Computational Techniques in Irrigation (Differential equations, linear algebra, numerical methods, application in irrigation, mathematical programming)" in the Irrigation Engineering and Management Program, "Advanced Optimization Methods" in the Division of Industrial Engineering and Management, etc. AIT's engineering computing could also benefit from more power. But Prof. Ricardo Harboe, Chairman of the Division of Water Resources Engineering pointed out to me that by using PCs and workstations, while underpowered, will enable AIT graduates to transfer their skills more rapidly when they return to their home country, which is certainly not likely to have advanced computing facilities. Good point.

AIT Division of Telecommunications

This is the newest organization on the AIT campus. It is headed by

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who has been seconded from the Helsinki University of Technology in Finland. The government of Finland is also responsible for giving a large grant to AIT for establishing the Division and for constructing its building. For a number of years the Finnish International Development Agency has sponsored telecommunication training (in Finland) for people involved in a variety of projects in Asia. This was expensive and did not have an Asian focus, so after some evaluation by the UN International Telecommunications Union, it was decided to establish this program to train engineers in existing and emerging technologies as well as management techniques as applied to telecommunications. Prof. Sharma commented to me that within southeast Asia there is a widespread lack of efficient telecommunications networks, and also a massive disparity between services available in rural and metropolitan areas. Also, new technologies are appearing faster than developing countries can absorb them.

The Division received its first 25 students (master's candidates) one year ago, May 1991. Five specialization areas are offered to the students.

- Transmission systems,
- Switching technology,
- Telematics,
- Network planning,
- Telecom management.

At this point all six faculty members are European, although Prof. Sharma plans to appoint some Asians in the near future. There are several laboratories, and facilities include a DX200, a digital exchange donated by the Finnish telecommunications company Nokia. This is a modern system and will permit students and researchers to study operation, maintenance, and performance evaluation of a real network, and also permits experiments with new services such as ISDN and videotelephony. So far, there is no research to speak of.

I commented to Prof. Sharma that I would like to send him some of my reports, except that he didn't have an electronic mail address on his business card. He responded that he felt strongly that electronic communications such as voice, fax, and email were merging, that faxes were more common than electronic mail boxes, and that vast numbers of people already had an electronic address in the form of a telephone number. All true, but at the moment he can't receive anything from me.

Another new laboratory in the Division of Industrial Engineering and Management is the CIM (Computer Integrated Manufacturing) Lab, which opened in September 1992. The first batch of ten students (from the Philippines, Bangladesh, Pakistan, and Thailand) arrived last summer. The lab has a collection of CAD/CAM software running on the IBM 3083 and IBM graphics workstations as well as microcomputer based software (MicroCADAM, AutoCAD, CADMAN B). The manufacturing section includes some production CNC machines and various training systems and computers. We did not have the opportunity to view this facility.

The history and needs of Asian countries has influenced the programs at AIT. Institute documentation as well as personal conversations with faculty were replete with pointers to work associated with resource-conservation, industrial waste, soil, construction technology (foundations, concrete, etc), urban planning, environment, and land use.

AIT differs from other academically oriented institutions in Asia that either use English extensively or rely on Western staff (such as Hong Kong University of Science and Technology, Institute for System Science in Singapore, or Pohang Institute of Technology in Korea, for example) in that AIT really does not expect to do world class research. Instead AIT is focusing on solving practical problems that can transcend borders within this part of the world. Because countries in the region have so many needs, the educational tasks confronting AIT are tremendous. Applied research here can have an immediate benefit on the lives of many human beings, and this could be a strong motivation for Western scientists who would like to visit and engage in joint work. Certainly, the Computer Science Division could ben-efit from senior visitors who wanted to help in the solution of engineering problems.

AIT graduates pop up in a large number of positions throughout the region's science and technology infrastructure. With 800 students, even small contributions are visible. Countries and institutions that support AIT know that Asian memories are long and that repayment will probably come at an unexpected time or place. AIT is the most international institution that I have seen here in Asia, proof that some things can be constructively shared. In the long run though, AIT needs to build a base to allow it to have more (and more senior) Asian faculty. Also, I wonder if AIT will become more heavily Thai oriented, especially as other countries increase their own technological capabilities and see less necessity for the expense of sending students to other countries.

INTERNATIONAL SYMPOSIUM ON COMPUTER ARCHITECTURE 1992

The 19th Annual International Symposium on Computer Architecture (ISCA) was held from May 19 through 21, 1992 at Queensland, Australia. This event is one of the highlight conferences of the year and covers various aspects of computer design, including novel memory and cache organizations, new communication mechanisms for multiprocessors, simulation studies of processor architectures, and postmortems on experimental machine projects. In attendance were most of the prominent researchers in the field from academic institutions and industry. Following the conference, a series of more focused workshops were held for smaller groups of researchers. This report describes our impressions of the conference, those topics of interest to our own research, and a summary of the workshop we attended.

Stephen W. Keckler and William J. Dally

INTERNATION SYMPOSIUM COMPUTER ARCHITECTURE

The primary purpose of our trip was to present our paper *Processor Coupling: Integrating Compile Time and Runtime Scheduling for Parallelism*. In it we describe a novel processor architecture that exploits instruction level parallelism by using wide instruction words and manages interthread parallelism by allowing multiple threads of control to be active and executing simultaneously. This work is a part of the MIT M-Machine that is currently being designed. The paper was well received and the forum provided useful feedback. Concerns raised by some in the audience centered on the complexity of the design (multiple function units and multiple threads on a single chip) and on the validity of our simulation results given that current compiler technology is more advanced than the compiler we used in our experiments.

This particular conference had a bumper crop of papers on multithreaded architectures, with two sessions devoted to multithreading. The paper that was most applicable to our work on Processor Coupling was *An Elementary Processor Architecture with Simultaneous Instruction Issuing from Multiple Threads*, by Hirata, et al., of the Media Research Laboratory of Matsushita Electric Industrial Company in Japan. This paper describes an architecture in which multiple threads are simultaneously active and share use of multiple function units. However, each thread may issue at most one operation per cycle, and conflicts between threads for execution units are resolved by dynamic arbitration. Stalled operations are stored in standby stations, while the thread may continue to issue operations to other function units. One interesting result that they found was the effect of load-store bandwidth on performance. Their reported speedup for 8-thread slots increased from 3.2 to 5.8 when they doubled the number of load-store units. Although not discussed in the paper, the talk presented some additional work on multiple instruction issue by a single thread using a dynamic superscalar approach. Their organization differs from Processor Coupling primarily in that they centralize the thread state (including register files) and parcel operations out to function units. Processor coupling distributes as much state as possible to the function units and managers register coherence in software.

Also of interest to our work on the M-Machine was *Active Messages: A Mechanism for Integrated Communication and Computation*, by von Eicken, Culler, Goldstein, and Schauser of the University of California at Berkeley. They argue that active messages, which is a communication mechanism that integrates message information into ongoing computation without requiring

buffering of the message, is useful in fine grained parallel computation. They evaluate the cost of implementing active messages on several commercial and research machines, including our MIT J-Machine, concluding that a few additional architectural features would make implementing active messages more efficient. These include user-level interrupts as well as lightweight message handling such as fast context switching or a message coprocessor to handle messages without disturbing the computation processor.

Two papers on adaptive routing in multicomputer networks might be of interest in the design of the M-Machine network; *Planar-Adaptive Routing: Low-cost Adaptive Networks for Multiprocessors* by Chien and Kim from the University of Illinois, and *The Turn Model for Adaptive Routing* by Glass and Ni of Michigan State University. The planar-adaptive technique routes messages in a k-ary n-cube in a series of 2-D planes, thus simplifying the routing algorithm and the switch complexity. The turn-model argues that the deadlock in adaptive networks caused by a cycle in the resource acquisition graph can be eliminated without requiring additional virtual channels; the solution prohibits particular turns (changes in dimension). This results in a family of algorithms such as "west-first" and "north-last." Both planar-adaptive routing and the turn model provide a restricted form of adaptive routing that is faster and less expensive to implement than fully adaptive.

One last note about the conference concerns the invited talk on the MIPS R4000 given by John Hennessy of Stanford University and MIPS Corporation. He spent most of the talk describing the architecture, but we were most interested in his comments on the design effort. They spent two years going from design specification to first silicon and another year to reach full production (first quarter, 1992). In the process, they had a peak of 56 hardware designers (33 sustained); not included were any software people. The entire project required an investment of approximately $40 million. Dr. Hennessy's viewpoint, then, was that it is not feasible to build interesting hardware in an academic setting because of the design effort and cost required. It is interesting to contrast this with the design of the Message Driven Processor (MDP) here at MIT, which took six designers four years to go from specification to production silicon. The MDP is the processing node for the J-Machine.

Multiprocessor Workshop

Following the conference, we attended the workshop "Future Multicomputers: Beyond Minimalist Multiprocessors?", in Hamilton Island, Australia. Two major issues were discussed: compilation and grain size of multicomputers. Monica Lam of Stanford University first discussed the compilation problem of parallel programs for multicomputers. Her thesis was that to manage parallelism effectively, a multicomputer must reduce communication and synchronization, as well as hide latencies, data coherency, and address translation mechanisms. Dr. Lam claims that this leads directly to coarse grained tasks and the use of prefetching remote data instead of multithreading to hide latency. However, she has assumed that the costs of communication are in fact large and did not consider fine grained tasks with fast communication primitives. Dr. Marina Chen of Yale University then described the tension between exploiting locality and ease of programming. She reiterated the importance of inexpensive communication and synchronization in developing parallel applications.

The grain size discussion divided the workshop participants into "fine-grained" and "coarse-grained" camps, with the latter group being much larger. Grain size was defined as the amount of memory local to a processor in a multicomputer. William Dally of MIT argued for fine grained nodes based upon silicon area costs. Given a machine with a fixed amount of memory, Dr. Dally claimed that since processor area is dwarfed by DRAM area, balancing processor and memory costs results in more nodes, each with 5-10 Mbytes of memory. The coarse grained camp demanded proof of programmability of such a machine. John Hennessy of Stanford University argued in favor of coarse grained nodes based on integrated circuit market prices. He conceded that fine grained machines have better performance per dollar, and in some restricted cases (Vector, SIMD) are easier to compile too. However, he claimed that multicomputers should be built with off-the-shelf microprocessors, which will provide an upwardly compatible product line, better developed software systems, and a large amount of memory (50-100 Megabytes per node). Dr. Dally's arguments were consistent with his view of experimental machines, while Dr. Hennessy showed his pragmatism and ties to products of the next 2-4 years.

In summary, the papers presented at the International Symposium on Computer Architecture represent state-of-the-art research in computer design. More so than in the past, research is focusing on multiprocessor and parallel computer architectures, and emphasis is being placed on multithreading and on interprocessor communication. Other researchers are trying to push uniprocessor performance by exploiting instruction level parallelism through both compiler and runtime techniques. The subsequent work-

shop brought together researchers whose primary work has been developing parallel hardware and software systems. The discussion of grain size in parallel machines sharply divided the audience into "coarse grain" and"fine grain" advocates. Those in favor of coarse grained processors based their arguments on programmability, while the fine grained spokesmen want to exploit the concurrency and cost efficiency available infine grained machines. However, the difference between the coarse grained and the fine grained designs in question differ by less than one order of magnitude in memory capacity per node.

Stephen W. Keckler is a Ph.D student at the MIT AI Laboratory. He worked as a circuit designer at Intel on the 386SL microprocessor. His research interests include computer architecture, parallel processing, and VLSI and system design.

Keckler received a BS degree in electrical engineering from Stanford University and an MS in electrical engineering and computer science from MIT. He is a National Defense Science and Engineering Graduate Fellow, and is a member of the IEEE, Sigma Xi, and Phi Beta Kappa.

Dr. William J. Dally received a B.S. degree in electrical engineering from Virginia Polytechnic Institute in 1980, an M.S. degree in electrical engineering from Stanford University in 1981, and a Ph.D. degree in computer science from Caltech in 1986. From 1980 to 1982 Dr. Dally worked at Bell Telephone Laboratories where he contributed to the design of the BELLMAC-32 microprocessor. From 1982 to 1983 he worked as a consultant in the area of digital systems design. From 1983 to 1986 he was a research assistant and then a research fellow at Caltech. He is currently an associate professor of computer science at the Massachusetts Institute of Technology. Dr. Dally's research interests include concurrent computing, computer architecture, computer-aided design, and VLSI design.

INDUSTRIAL AUTOMATION AND RELATED ACTIVITIES IN SINGAPORE

The Industrial Automation'92 Conference, Singapore, held in May 1992 is summarized. In addition the capabilities of the Singapore Institute of Standards and Technology and the new Institute for Manufacturing Technology associated with Nanyang University are described.

by David K. Kahaner

INTRODUCTION

Earlier reports have discussed the computing and factory automation situation in Singapore,

> ["singapor", 19 Jun 1991;
> "dattab", 16 Sept 1991;
> "iccim.91", 4 Nov 1991]
> (E-mail:
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as well as the general science structure of this small country.

Since the 1950s, Singapore's annual per capita income growth has averaged more than 6%. The country began building a manufacturing base in the late 1950s based on textiles, moved upstream to simple electronics, and then to advanced electronics. It has made major gains as a financial center and is currently looking at biotechnology as a new growth industry. Actually, there is some indication that Singapore's income growth has been as much a result of the generous subsidies to foreign corporations that invested there as they have to productivity gains in manufacturing. Foreign investments have been huge. In 1992, U.S. firms will invest almost US$1B, an increase of over 30% from a year earlier. Estimates of U.S. investments in other southeast Asian countries show that only Indonesia ($1.9B) and Malaysia ($1B) will have a greater infusion of U.S. capital.

Computer technology is very heavily infused into Singapore's infrastructure. A new project began this year is the development of a manufacturing information network (Manunet). Starting first with metal and plastics fabrication, it will comprise updated information on automation products, suppliers, technologies, and patent details. Manunet will be expanded to include manufacturing services for engineering design. There are almost 3000 manufacturing companies in Singapore, most small-to-medium sized. These companies will invest more than $1B U.S. on automation within the next 2-3 years. The development of Manunet is to be done at the new Institute of Manufacturing Technology (IMT).

INSTITUTE OF MANUFACTURING TECHNOLOGY

In my earlier report [iccim.91], I described GINTIC (GINTIC Institute of CIM), a new computer-integrated manufacturing training and research facility on the campus of the Nanyang Technological University (NTU). Now NTU has established IMT as another new institute, focusing on manufacturing processes and manufacturing automation. I did not go to IMT (it is probably too early to see much) but was briefed about it by Dr. Beng Siong Lim, of GINTIC[GBSLIM@-NTUVAX.BITNET]. Like GINTIC, IMT will provide (graduate) training as well as research and development in an industry-driven way. For example, one immediate task is to work with computer disk drive manufacturers to improve that industry's manufacturing, testing, and maintenance infrastructure. IMT has also identified these ten projects of interest.

- Disk drive head mounting, alignment and fabrication
- Multilayer ceramics
- Electron microscopy of large plate weldments
- Near net shape precision casting and molding
- Waterjet cutting
- Laser machining
- Robotic vision-assist welding
- Crane robots
- Advanced surface technology,

including SMT technology
Garment material optimization.

The philosophy of research is interesting. I quote from their brochure. "Postgraduate research experience at IMT need not necessarily involve hi-tech, in the sense of the latest, glamour-type research (e.g. robots, AGV (autonomous guided vehicles) superconductivity, etc.) but enabling technologies. We have to bear in mind that new markets taken in by the multinational companies require substantive support from home grown small- and medium-sized enterprises, particularly in well developed and proven techniques of established manufacturing, such as casting, heat treatment, automation interfaces, part feeders-we have not yet reached the critical mass in this know-how. Some of them have evolved from hundreds of years into reliable, proven techniques of mass production."

A building is being constructed for IMT on the NTU campus, and the first part, to be opened in 1994, is budgeted at about $6M U.S. Eventually IMT will cover about 12,000 m^2 of lab space and workshops and will have a research staff of 200. IMT's model is the German Fraunhofer Institute (IPA), using its operational policies such as industrial-oriented research and active interchange of staff with industry in Singapore. There is also a plan for significant interchanges with Germany, particularly with the State of Baden-Wurttenburg.

I expect to visit IMT during my next trip to Singapore. In the meantime, further information can be obtained from the following:

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SINGAPORE INSTITUTE OF STANDARDS AND INDUSTRIAL RESEARCH (SISIR)

My visit to SISIR was hosted by

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SISIR has missions somewhat similar to the U.S. National Institute of Standards and Technology (NIST), the former National Bureau of Standards (my home organization). In fact, in the Measurement Standards Center, Dr. Sze Wey Chua has been working with scientists at NIST on voltage standards through sponsorship from the United Nations. He also explained to me that SISIR has MOUs (memoranda of understanding) with China (PRC), Taiwan, and Australia on related work. SISIR also has an MOU with the British Standards Institute (BSI), based on the International Standards Organization (ISO) 9000 standards.

SISIR has a staff of about 450 and is 80% self-financed. Its programs are divided into two areas: hard technology—including contract R&D, process or product design/development, consulting/training, testing, evaluation and failure analysis; and soft technology—including standards/certification, quality assessment issues, accreditation, technology transfer, and incubation. In addition to the usual R&D associated with measurement standards, SISIR is building a food biotechnology center and an electromagnetic compatibility test center. There are already centers for chemistry, polymers, metals and advanced materials, surface and particle technology, mechanical technology, information technology, electronics testing, and design and development. Singapore will soon join Japan as the only Asian countries with accreditation from the Electrotechnical Commission, meaning that Sinaporean electronic products will be much more readily accepted in the West (especially Europe).

Although I received a briefing on SISIR's overall activities, I was most interested to meet scientists with computer interests. I found two. Dr. Henry Hechneng Sun (Mechanical Technology Center) has been doing finite element analysis on scaffolding in shipyards and also analysis of blast deflectors inside jet engines. This involves using various engineering analysis packages; Dr. Sun is not developing his own software. Like many Singaporean scientists, Sun spent time in the United States, at NASA and the University of Cincinnati.

Dr. Tao Zhuang, originally from the PRC, worked on nonlinear fracture mechanics in China and at Syracuse University. His main interests are in crack propagation perpendicular to interfaces of laminated materials, and his work has been applied to studies of armor plates in the PRC. This type of analysis is highly nonlinear and can benefit from large-scale computer modeling, as well as serious analysis. Unfortunately, SISIR is heavily contract-oriented, and there is not much call for this kind of research. (I feel that there are good opportunities for collaboration with Western

researchers who can provide Zhuang with the facilities he needs.) Lately, he has been working on laser welding for the aerospace industry and on various crack testing (low-temperature environment) strategies. One of his projects is for the Chicago Bridge and Iron Company.

I was surprised to see the significant number of papers on industrial automation that were presented at IA'92 by SISIR researchers (see below).

Finally, I should note that like other Singaporean government organizations, SISIR has an astonishingly complete and coherent set of English language documents. Perhaps it is not surprising, but English is the language of business here, and it is probably easier for English speakers to operate in Singapore than anywhere in this part of Asia. Of course, many people also speak Malay, Tamil, or one of Chinese languages.

2ND ASIA-PACIFIC INDUSTRIAL AUTOMATION CONFERENCE (IA'92)

Singapore has established itself as the international conference center of southeast Asia. Although the first IA Conference was held in 1990, there have been many computer-related meetings and expositions since then, including a Computer Integrated Manufacturing (CIM) conference that I reported on last fall. The conference was held in Singapore's World Trade Center. There was a large exhibition at which a variety of vendors displayed flexible manufacturing systems, robots, storage and retrieval systems for factories, pneumatic and hydraulic components and systems, CAD/CAM packages, and test measurement and control equipment. There was also an impressive technical program of about 75 papers in two parallel tracks extending over three days.

Not unexpectedly, the featured speakers were all from the West—U.S., U.K., Sweden, and Australia. It was also true that the most fascinating work described was from the West. Singapore has made remarkable progress in its manufacturing capabilities, but it is now trying to develop its own expertise. As mentioned above, there has been a tremendous amount of foreign investment but not always transfer of technology. Most of the manufacturing activity in Singapore is from small- to medium-sized companies, with little incentive to conduct basic research. The National University of Singapore (NUS) has a manufacturing research component, but many of the papers presented here from NUS reflected a lack of real, hands-on experience and were often about simulations. There were, however, some very interesting ideas described, and it is clear that Singaporean scientists have a good sense that the battle for flexible assembly in the 1990s will be in software. (Also, some very interesting papers were developed jointly with Western scientists.) There were excellent contributions from the (still largely unknown) Nanyang Technological University.

As mentioned in the preceding section, this is where the government has decided to set up two major manufacturing institutes, the GINTIC Institute of CIM and the Institute of Manufacturing Technology. Even here, the emphasis is on developing home-grown expertise, learning, and more cost-effective solutions rather than completely breaking new ground. I expect this trend to continue. A very good example was given by Ng Kok Loon, former deputy director of SISIR, on free-ranging AGVs. Loon now has left SISIR to set up a company to develop such vehicles. Unfortunately, his paper was not included in the Proceedings, but Loon described the history of trackless AGVs (dead reckoning, laser beacons, inertial guidance, optical or ultrasonic imaging, optical stereoscopic, and others) and then presented a product prototype (available as a real product by the end of 1992), using ultrasonics and transponders, which he claimed had a positioning accuracy of 10 mm. The point here is that this work is not really groundbreaking but that Loon and colleagues had what they felt was a very economical system (cheaper than lasers) that would be of Singaporean origin.

There were a few interesting papers that presented plans or proposals. The Singaporean government has developed an automation master plan, calling for stepped up work in five major areas—CAD/CAM/CAE, robotics, automated material-handling, computing technologies, and manufacturing production and control systems. The latter is the weakest area in Singapore, and there were several papers devoted to this topic. In large companies, (over $50M/year), production planning is done mainly with material requirements and manufacturing resource-planning systems, but they are not regarded as very successful. Smaller companies (US$10 to 50M/year) almost all use manual production planning and control. It is estimated that about 600 or more manufacturing companies in Singapore are in the second category, and the institutes, universities, and government labs are seeking solutions for them. This involves capacity planning, material planning, and activity planning. The latter seemed most interesting to me, as the techniques to deal with it are more computer-based, such as

Analytical models
(branch and bound,

dynamic programming, etc.)
Knowledge-based search methods heuristics)
Simulation and optimization (artificial intelligence (AI) techniques)
Alternative evaluation (depends of list of alternatives)
Human-computer interaction (not a technique as a way of making changes)

Scientists from SISIR gave an overview of an intelligent dynamic production scheduling system (IDPSS) that they are hoping to develop after two years of work. Another SISIR project is the creation of a knowledge-based interactive real-time control system (KIRCS). This was done jointly with U.K. scientists in collaboration with IBM. There were several papers on materials handling, as the Port of Singapore is extremely large, and automating processing there motivates factory automation by other local manufactures.

In a supplement to this report (File ia92.abs), I give the titles, authors, and abstracts of all the papers. Here I mention a few (Asian-based) papers that were of particular interest to me. The single thread that held together many of the papers was integration within a company. That is, individual tools, such as CAD, are difficult to justify alone but instead need to be seen as one part of a company's business strategy. In that sense there were several comments to the effect that use of robotics was less than had been predicted because their efficiency within the total organization was questionable.

G.C.I. Lin's paper on AutoLay was useful because he surveyed and compared the existing PC-based facility layout programs. AutoLay is an Australian package written in LISP and integrated with AutoCAD.

Lin also spoke about a newly developed optimization and simulation package that his group has developed (CIMOS), to run under Windows; CIMOS is an iterative system that progresses from spreadsheet to AI to knowledge-based techniques and has a strategic view of the manufacturing structure. I thought this was a very impressive piece of work by a scientist who has been involved in manufacturing for decades. Western researchers should make an effort to communicate with Lin. (See abstract in my supplement.)

There were several papers describing experiences with simulation packages (especially on PCs), and these were probably useful to listeners who might not have access to a wide selection of programs to choose from.

To my taste, one of the most interesting papers was presented by M. Ang (National University of Singapore, E-mail: MPEANGH@NUSVM.BITNET). (Ang's Ph.D. degree is from Rochester.) Ang asks, "Why are robots not so pervasive in industries [as they should be]? Automation has penetrated manufacturing industries in doing tasks that humans cannot...requiring high positional accuracies and speed which humans do not possess." Ang's focus is on developing robots to do those things that humans can do well or with ease--opening a bottle, putting a cap onto a pen, picking up a glass of water or some eggs, etc. He feels that we need to be moving toward a generation of robots designed for jobs requiring both force and position control, with the former being the more important. This is not really new; eventually it comes down to "compliance" of the manipulator end effector. (In fact, a similar comment was made by P. Mills, from Adept, in the U.S.) Compliance is described by the (symmetric positive definite stiffness) matrix that relates forces and torques, acting on the end-effector to its translational and angular displacements. What Ang wants to do is specify the matrix elements in order to perform a specified task, and then to determine how to build a system with those parameters. What is interesting about this approach is that it requires the solution of an optimization problem, because the stiffness matrix elements are undetermined. As an example, Ang works through two specific problems--a CAM and surface follower and grinding/polishing against a rotating belt. His approach is mechanistic and involves setting various matrix elements to zero, but it strikes me that more careful analysis could make a significant improvement. In any case, this is a very interesting direction and worth encouraging. Ang presented similar ideas at IA'90, which were co-authored by G. Andeen, from SRI. Earlier, Andeen also wrote about compliance in the following paper.

G. Andeen and R. Kornbluh, "Design of Compliance in Robots," in the Proceedings of IEEE International Conference on Robotics and Automation, Philaelphia, PA, April 1988 (pp. 276-281).

A somewhat related paper was by G.C.I. Lin (University of South Australia) on the development of a soft sensor for force and torque sensing. (This was the third paper by Lin's group.) The prototypical problem is to place a peg into a tight hole. Lin has designed a very simple wrist-mounted force/torque sensor and uses some electro-optical transducers as sensing elements. The software is more complicated though and uses a neural net to process the sensor light signals.

A mathematical paper, not related to the above but including interesting numerical approximation ideas, was given by Duggal et al. (NTU) on process modeling and fault diagnosis using real-time state variable methods.

Another interesting paper from Singapore, although not well related to the topic of the conference, was Ngoi's, in which he discusses using color segmentation to help in the recognizing of 3-D objects. The application considered was a segmentation of surface-mounted devices (SMDs).

There were a set of papers introducing and illustrating the use of neural nets and fuzzy controls. This is now well integrated into the practicing engineering community, and applications to such things as PCB visual inspection systems were presented.

An excellent survey paper was presented by K.B. Lim (NUS) on the Singaporean precision engineering and metal working industries, which in 1989 had an output of US$6.6B, about US$4B. Lim gives a history of the industry and presents the difficulties and solutions they encounter on the road to automation. Two conclusions are developed—that Singapore's Economic Development Board (EDB) is doing a good job monitoring and assisting these enterprises and that the lack of skilled workers is the main impediment today. There were also other papers presented on specific applications to metal processing, steel and aluminum coils, etc.

There were too many Australian-based papers to discuss individually, but I note one by H. Thorne (University of Adelaide) on costing system problems at the AWA Defense Industries, the largest defense systems and software engineering companies in Australia.

A speaker from the Singaporean subsidiary of the Japanese company Yamazaki Mazak spoke about the CIM factory his company recently built in Singapore, the first in southeast Asia. (Since 1983, this company has built and is using an unmanned plant in Japan and has other large plants in Japan, the U.S., and U.K.) It is clear that if Singapore can extract some of this technology to use in its own organizations, it will save years of relearning lessons already understood by established companies in Japan and the West.

Other Japanese contributions were modest and mostly from academia. One exception was M. Yoshitake, who is a senior consultant to the Automation Application Center, set up by the Singaporean government. Yoshitake discussed the use of a versatility index (VI) proposed in IA'90 by H. Makino and related to the number of model changes per year occurring in an assembly process. This seems like a simple idea, but Yoshitake has done a study of various assembly systems and applied the results to draw conclusions about PCB production. Some systems have VI values over 1000, meaning that models change more than once every two hours.

Several papers were submitted by PRC scientists, but these people were unable to attend.

Loh and Nee (NUS) gave a paper about packing hexahedral boxes, a potentially interesting 3-D problem. Their method is layer by layer and totally heuristic, but it did give 65% packing efficiencies, not a bad figure (this degrades rapidly as a function of the depth of packing volume.)

From a cultural point of view, the most interesting paper was from two Pakistani scientists, discussing issues related to implementing CIM in their (Third World) country. They discussed justifying CIM to management, the relation of government to industry, and social, technical, and managerial issues. They made an excellent point, which applies equally well in the West, that "it is easier to educate (manufacturing) engineers about computers than computer professionals about manufacturing."

There was one (rather theoretical) paper on the topic of inspection from a Malaysian academic but no indication was given that the ideas had been implemented in a real situation.

I would like to mention the excellent keynote papers. Because these were all given by Western researchers, I will not dwell on them, except for very brief remarks. G. Netzler gave an overview on the use of AGVs in factory automation, particularly a new laser guidance system that requires no floor marks (angles are measured between reflector tapes on the wall), thereby simplifying route changing, etc. This system is now in use in Singapore (in their very large port facility.) Netzler responded to questions about vision systems as possible for the future but not yet for practical use. He also observed that an obvious future direction is to mount robots on AGVs to make them mobile. (Also see my comments about Loon's paper, above.)

F. Riley's (Bodine Corporation) keynote speech would have been perfect as a closing lecture rather than an opener. He emphasized that "manufacturing engineers must develop their proposals for automation in the light of strategic issues [rather than] reducing unit cost of production to the lowest level. Engineers [must] sell factory automation to the nontechnical management on the basis of its ability to meet customer expectations [and not] put such heavy reliance on

direct labor reduction. This is far more important in the emerging countries of the Asian-Pacificarea. Present management of countries in this area is not attuned psychologically to turning from their human resource management skills to automation. Engineers must become the instrument of change by changing corporate attitudes toward the usefulness and market benefits of successful automation.... Judge papers not solely in the light of their technological content, but how utilization might be sold within your own corporate structure not only as useful, but most importantly, as ultimately profitable."

SMALL COMMERCIALIZATION OF AUTOMATIC DIFFERENTIATION IN JAPAN

This paper reports on an example of a commercial automatic differentiation product. Automatic differentiation is distinguished from symbolic differentiation and numerical differentiation.

by David K. Kahaner

In numerical differentiation, a different quotient (or a sophisticated variant) is evaluated to obtain an approximate numerical value for the derivative of a given function. Of course, the limit of such a quotient is just the definition of derivative that is studied by all scientists. The approximation is just that, and its accuracy in principle depends only on the increment used to separate the function values (truncation error). In practice, the accuracy of the approximation also depends on characteristics of the computing environment on which the calculations are performed. Unless rational (exact) arithmetic is used, there will also be some numerical or roundoff error, and the combination of both determines the accuracy of the final approximation to the derivative. But in any case, the result is an approximation. Within the context of engineering computations, numerical differentiation is the usual approach.

Symbolic differentiation begins with an algebraic expression (formula) for the function and produces a formula for the derivative. The latter can be evaluated, and if the evaluation is exact, the value of the derivative will be too. Symbolic differentiation, as part of the more general field of symbolic computation, has grown in popularity over the past few years, and there are now well known commercial products such as Mathematical that are available for use even on personal computers. The advantage of symbolic computation is that a formula can give insight that a number cannot. Disadvantages have been that not all functions are expressed by expressions (table lookup multilevel subroutines, special functions of physics given by approximations, etc) and that symbolic computation can be very expensive.

Automatic differentiation is a process that obtains numerical values without generating a formula for the derivative and without the truncation error of numerical differentiation. The only errors introduced are those associated with the use of real, as opposed to rational arithmetic. Automatic differentiation requires the use of differentiation arithmetic, which is related to interval arithmetic introduced by R.E. Moore [1], and further developed by L.B.Rall [2]. It depends on the arithmetic of ordered pairs, i.e., a set of rules for manipulation (+,-,*,/) similar to the ordered pair of rules for complex arithmetic, or the rules for rational arithmetic. Automatic differentiation might be considered as somewhere between symbolic and numerical differentiation. Its computational cost is greater than that of numerical differentiation, although it also produces a numerical value.

The process of automatic differentiation can be extended to higher order derivatives, Taylor coefficients, etc. Rall and Corliss have applied it to generate remainder terms for the errors associated with numerical evaluation of integrals with validation, and there is an IBM product associated with that work. It has also been used as part of optimization techniques. John Dennis (Rice) and Andreas Griewank (Argonne National Lab) are currently engaged in a project to do automatic differentiation in optimization problems. There was also an optimization language called PROSE developed in the 1960s, which used automatic differentiation.

It is clumsy to take advantage of automatic differentiation using traditional languages like Fortran or C on computers. The main effort in the United States has been to use languages that have extensions for interval analysis. Languages that permit operator overloading and data types are better than Fortran for this purpose. Pascal-XSC language has a complete set of routines for automatic differentiation as part of its

support package. Automatic differentiation in Japan also has a respectable history, and Professor Masao Iri and his colleagues at the University of Tokyo developed a Fortran precompiler some time ago.

In the United States, the main "market" for automatic differentiation has been other scientists that develop algorithms, rather than end users with direct engineering applications. The theory behind automatic differentiation is valid, but its proponents have had difficulty explaining it to other scientists, and have not yet been able to produce a sufficiently convincing practical application. Last year, Rall claimed "that my main contribution to the subject was to put up with 25 years of indifference to it and its usefulness."

Recently I discovered an authentic application marketed by a small company in Japan.

> Information and Mathematical Science Laboratory, Inc. (IMS)
> Idebukuro Aoyagi Bldg, 2-43-1
> Ikebukuro, Toshima-ku, Tokyo
> 171 Japan
> Tel: +81 3 3590-5211;
> Fax: +81 3 3590-5353

IMS was founded in 1974 to do software development, systems integration, and related consultation. Last year's gross sales (1991) were 850M Yen (about US$7.5M). The company develops and supports a collection of software that includes a Fortran static analyzer and checker, a Unix terminal emulator, and various engineering analysis packages, such as for bearing-motion and planar/linear antennas.

IMS's president, Mr. Akira Isono, explained to me that he first learned about automatic differentiation by studying Rall's 1986 paper [3]. With the help of some university consultants he directed the writing (in Fortran) of an automatic differentiation package that is now marketed under the name Texpander. This corresponds very roughly to the tool set that is available with Pascal XCS, although Texpander produces Fortran as output. Isono admitted that he has had difficulty getting users to buy it; the applicability of the concept is difficult for engineers to grasp. A user manual has several examples, such as the computation of Taylor coefficients for f(x)=sqrt(x), centered around a point "a". But, perhaps this is a bit too esoteric for practical engineers. Also, the Fortran output of Texpander is five to six times larger than a comparable numerical differentiation program, and also it runs slower.

However, Mr. Isono has also used Texpander to develop Planc, a package for the analysis of planar and linear antennas. This was also written in Fortran, although the user interface is written in C. In this case, automatic differentiation is used to generate a sensitivity analysis for the parameters defining the antenna. Isono claims that Planc is selling much better than Texpander. He also uses Texpander to do sensitivity analysis for structural engineering, and for some of the optical analysis associated with accelerator beam control. His current project is to enhance Planc to perform parameter optimization—this is similar to the general optimization problems considered by Dennis and Griewank mentioned above, but much more focused.

I was not able to examine the source program for Texpander or Planc. What impressed me was the concept of using automatic differentiation to help solve a specific engineering problem. Feedback from such efforts is very effective in determining the applicability of relatively theoretical concepts, and of course, in making improvements.

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NETWORKING IN THE PEOPLE'S REPUBLIC OF CHINA

A description of networking activities in the People's Republic of China (PRC)

Franklin F. Kuo

At the invitation of the China Institute of Communications, the Citizen Ambassador Program of People to People International arranged a visit for a delegation of professionals in telecommunications and networking technology to the People's Republic of China. I was the leader of the delegation whose purpose was to exchange information and solidify contacts with Chinese professionals within the computer and communications industry. The exchange focussed on topics dealing with China's telecommunications infrastructure, especially on subjects relating to current research and applications in computer networks. This group, known as the Networking Technology Delegation, consisted of 24 members, with 18 professionals and 6 accompanying spouses. Of the 24 there were 17 people from the United States, 5 from Japan (2 U.S. citizens residing in Tokyo) one from Germany, and one from Hong Kong, so it was truly an international group. Six members of the delegation were native Chinese speakers, which made it very convenient in our travels.

The itinerary for our trip was as follows:

May 11-15, 1992 Beijing
May 15-19, Xi'an
May 19-22, Shanghai
May 22-24, Hong Kong

Our professional visits concentrated on telecommunications and on computer networking. We visited a number of the major research institutes and universities in Beijing, Xi'an and Shanghai. In all three cities a lot of interest in computer networking was evident, especially in the Internet and how to connect to it. Another question that frequently came up was the future of OSI vs that of TCP/IP. There are a lot of local area networks in operation in China, which connect many PC-clones, mostly Chinese produced, to some older generation mainframes such as Honeywells. What we did not see were operational wide-area networks (WAN), with the exception of a metropolitan demonstration network in Beijing.

Current Wide-Area Networks

At present, the major WAN in China is the China National Public Data Network, CNPAC, that is currently being developed and implemented. CNPAC, an X-25 packet switched network, is designed to carry data at speeds varying between 1.2 and 9.6 kbps. The hub is in Beijing, where the network management center is located, with packet switches sited in the major cities of Shanghai and Guangzhou, and PS concentrators found in other major cities. The packet switches, concentrators, and PADs (packet assembly/disassembly devices) are all manufactured in China. At the Beijing hub, there is an international access line to CNPAC. Since we did not see a CNPAC demonstration, it is not clear how much of it is operational and how much is still under development.

Other private data networks are used in China in applications, in the railway system, banking system, and civil aeronautics.

In China, an X.25 link to the Internet uses a store and forward system via the CNPAC international access line in Beijing connecting to the University of Karlsruhe, Germany. To the outside world, this link is being called "the China Academic Network (CANET)." In addition to CNPAC connectivity, there is dial-up access to CANET from inside China. David Kahaner of ONR Tokyo reports that he frequently communicates with Chinese scientists via CANET. However, many of the Chinese networking specialists we talked to have never heard of the

name "CANET," so we suspect that CANET means more to the outside world than in China.

The major problem confronting the development of WANs in China is the poor telecommunications infrastructure. Since the penetration of basic plain old telephone service (POTS) is less than 1% among Chinese businesses and households, and since local and long distance telephone switching and transmission facilities are inadequate and antiquated, it is difficult to build a modern computer network upon the current telecommunications infrastructure. It will take decades to bring the basic telecommuncations system up to modern standards, so Chinese networking will take a long time to come up to western norms also.

Metropolitan and Campus Networks

In Beijing, we witnessed a very impressive metropolitan networking project called NCFC (National Computing and Networking Facility of China). NCFC is a demonstration network in Beijing that links the two major universities, Tsinghua and Beijing Universities to a number of research institutes of the Chinese Academy of Sciences (CAS). Each of the pariticipating institutions have campus networks like the TUnet of Tsinghua University. These campus networks are connected by NCFC as a two level system. Currently NCFC has a 10 Mbps backbone connecting the three campus networks that will increase to 100 Mbps in the next phase of the project. Communication protocols will be ISO/OSI, but TCP/IP is the first phase protocol. The top level of NCFC consists of the backbone and the network control center. The second level is composed of campus networks at the two universities and CAS. NCFC is the largest and most ambitious networking project we saw in China. It is partially funded by the World Bank and the State Planning Commission, and is in limited operation now, with full operation expected by 1994. We visited two of the three groups that are participating in the development of NCFC. The first was the Computer Network Center (CNC) of the Chinese Academy of Sciences, with its own campus network, the CASnet. The CNC seems to have the major responsibility for the development of NCFC and is staffed by 40 professionals. The second group, at Tsinghua University, is described below.

The Tsinghua University Network (TUnet)

The most impressive university networking group we visited was at Tsinghua University, the premier technical university in China. Under the direction of Professor Hu Daoyuan, the Tsinghua University network, TUnet is being developed under a well laid-out strategy based upon the following goals:

1. It will be a universal, comprehensive campus network; its usage will include instruction, research, administration, library, and communications services.

2. It will be a multimedia integrated services network; messages transmitted in the network will include not only data, but voice and video as well.

3. It will operate under accepted international standards for interfacing devices to the network. Emerging standards are important in the fast changing technology of networking. Initially TUnet will operate under TCP/IP, but migration strategies have been adopted to migrate to ISO/OSI.

4. It will be a heterogeneous network that uses a variety of advanced networking technologies (LAN, PABXPS, ISDN, and FDDI) to interconnect multivendor computing facilities.

5. It will be developed in phases. The first phase (1987 to 1991) concentrating on interconnection of facilities, and the second phase (1992 to 1995) emphasizing network services.

In TUnet there are three major networking facilities:

a. A circuit switched network based upon an integrated services PABX,

b. A packet switching network based upon X.25 switches and PADs,

c. Ethernet LANs interconnected through a 100 Mbps FDDI optical fiber backbone.

A key function of TUnet is electronic mail. Tsinghua University's message handling system (MHS) funtions includes mail, telegraph, teletext, fax, videotex, voice, and images. The MHS is based upon the EAN system developed by the University of British Columbia conforming to the CCITT X.400 recommendation series of 1984. Tsinghua's work on its e-mail system includes migration, Chinese localization, menu adaptation and the implementation of remote user agents.

The work at Tsinghua on TUnet and NCFC underlines one of the basic constraints that Chinese net-

working technologists must live with. Unless you have foreign (hard) currencies to purchase networking equipment, you've got to design and build everything from scratch, including hardware and software. So TUnet represents in many ways a bootstrap operation. The people in TUnet are all very well trained and dedicated. It is unfortunate that they could not make use of technology that is readily available in the Western world.

Local Area Networks (LANs)

In China today many LANs are in use. Two common LAN products widely available throughout China are Ethernets from 3 COM, and Netware, a LAN operating system developed by the Novell company. These products are available in China because of joint venture arrangements that the cited companies have made with Chinese counterparts. Most of the LAN products are manufactured in China under license from U.S. companies such as 3 COM and Novell. At the Shanghai Jiao Tong University, Professor Yang Chuan-hou, the Director of the Computer Network Research Laboratory, presented to us some work that dealt with an architectural design of a gateway interconnecting LANs to an X.25 packet switched network. The work again was developmental in nature, in that both hardware and software designs were implemented in the laboratory.

Work like that of Professor Yang and his colleagues illustrates the practical nature of the networking development going on in China today. I visited China in 1984, when I was a World Bank consultant to Shanghai Jiao Tong University. In the intervening years, there has been an explosive growth in both computing and networking technology in China, which will only accelerate with the further penetration of the Internet into China. Since the Internet is capable of bringing network specialists and users throughout the world into a larger cooperating community, I believe that China's networking community will soon become full partner in this world-wide community.

TRANSPUTER MEETING AND INDIA'S PARALLEL COMPUTER

This paper summarizes the Fourth International Transputer/Occam Conference (Tokyo, June 92) and the Indian Transputer/Occam parallel computing project.

by David K. Kahaner

INTRODUCTION

A transputer is an elegant little processor that is produced in a variety of versions by the U.K. company, Inmos (newest is T9000), with respectable computing power. (The T800 has about 2 MFLOPS, or 13 MIPS of peak performance.) On one chip there are a CPU, a floating-point processor, built-in support for interprocessor communication, and microcoded context switching capability. Transputers have been configured as boards for PCs and in large parallel configurations with peak performance of several hundred GFLOPS. Transputers can be physically connected by four interprocessor communication links. The communication is not exceptionally fast, but it can be performed simultaneously with calculation. There is also a unique language, Occam, that appears to be a combination of parallel C with process control.

The main interest in transputers appears to be that a user can put together a system of one or more and get it up and running very easily. The four physical links make a two-dimensional mesh natural, but by software, other kinds of interconnections can be simulated, such as rings, pyramids, hypercubes, etc. Thus it is possible to experiment with a variety of parallel processing considerations, and several different companies produce both general and special purpose parallel computers that are transputer based. Not unexpectedly transputer use is highest in the U.K. and in Europe, but user communities exist in many other countries. I have noticed that universities in Asia looking for inexpensive ways to move into parallel processing often develop systems from transputers.

Discussions with Japanese scientists suggest that transputer activities are widely dispersed in Japan, especially focused on applications. Nevertheless, within the computer science community, transputers are not at the center of attention, although this is false for those institutes that have emphasized work on them. (I would like to hear some opinions about that point.) Weaknesses center on performance degradation with scale-up to larger systems, performance a bit behind other systems at the same point in time (one scientist commented that the T9000 would have been impressive if it was available a year and a half ago), weak compilers other than Occam, and general complaints about the difficulties using Occam.

The Fourth International Transputer/Occam Conference was held in Tokyo during the first week of June 1992. There were two days of tutorials, followed by about a dozen and a half conference papers. One third of these were authored in the United Kingdom or Europe and most of the remainder were from Japan. Approximately 100 scientists attended, perhaps 90 Japanese. Titles and authors of the papers are given in the Appendix. A proceedings was published and is available as follows:

Transputer/Occam Japan 4
S. Noguchi and H. Umeo, Eds.
Proceedings of the Fourth
Transputer/Occam International Conference
4-5 June 1992, Tokyo Japan
IOS Press
Van Diemenstraat 94 1013 CN
Amsterdam, Netherlands
For other details, contact one of the conference organizers.

Prof Shoichi Noguchi
Director, Research Center for Applied Information Sciences
Tohoku University
2-1-1 Katahira Aobaku
Sendai, 980 Japan

Prof Hiroshi Umeo
Dept of Applied Electronics
Faculty of Engineering
Osaka Electro-Communication University
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Osaka 572 Japan

Transputer meetings always seem (to me) a bit different from meetings about other parallel computers,

because they attract an interesting cross-section of users who are employing them to solve a variety of practical problems. At this meeting, even with such a small set of papers, the electric applications were obvious—data acquisition, control of power converters, VLSI logic simulation, car navigation, underwater acoustic communication, etc. There were also papers on numerical computation, including Cholesky decomposition, FFT, a two-dimensional particle-in-cell (PIC) for plasma simulation, parallel Lax-Wendroff algorithm, and a parallel implementation of 0-1 knapsack problems. For almost all of these papers, techniques already exist to solve the problems addressed or parallel algorithms are already known. The main emphasis here was to obtain an efficient implementation. For example, the FFT paper deals with an algorithm for implementing a 1-D or 2-D FFT on an eight-neighbor processor array. Such an array is obtained in software using the four communication links on each transputer. (The discrete Fourier transform is developed in powers of four, rather than two.) The linear algebra paper describes a variety of experiments on variously banded systems. There were a few papers with a computer science focus, message routing, and reduction by message passing. Two very interesting papers related to constraint satisfaction (using continuous and fuzzy variables), and multiagent planning. In these cases, the transputer is not a key ingredient, and Occam is simply used as an implementation language.

What makes transputers practical and intriguing for most of the speakers was that real parallel computing could be done with very small systems, typically only a few transputers. For example, the PIC paper deals with a problem that routinely is tasked to the largest supercomputers, involving a large Poisson solver and many particles. Here eight transputers were employed (maximum performance possible from the hardware was about 15 MFLOPS) and a total of 1000 particles were used. The authors were disappointed with the parallelization performance because the algorithm required too much waiting time between computation. A more positive result was obtained from a parallel implementation of the modified (explicit) Lax-Wendroff method, on a two-dimensional grid. The application applies to models of ionized gas in the solar atmosphere. The authors have a system consisting of three boards of eight transputers each in a NEC PC plus one transputer used as a "root"; the boards are produced by Concurrent Systems. For some reason, their implementation only used eight transputers plus the root, but they obtained almost linear speedup for this two-dimensional problem written in Fortran with parallel extensions. The authors conclude that while the run time for their system is about 20 times that of a Facom VP-200 supercomputer, both turnaround time and available memory are similar. Nevertheless, one feels that their primary reason for using the transputer system was that "unfortunately, we cannot access any supercomputer from our institute, so that it is difficult for us to contribute to the advance of astrophysical MHD in spite of our enthusiasm." Similarly, most of the other papers discussed systems of comparable size.

I attended this conference for two basic reasons—to get a scale of the work going on here (modest) and to hear about the activities in India.

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Dr. Joshi gave an overview of CDAC. I haven't yet been there yet but am scheduled to attend a meeting in December. Thus my description is based on Joshi's remarks only.

CDAC was set up by the Indian government about four years ago to address the high performance computing requirements of the country. At that time it was recognized that there were substantial computing needs not being met. These were in standard application areas such as fluid dynamics, engineering design, computational physics and chemistry, image and signal processing, climate modeling, and biotechnology. What computational work existed was being done on very low power mainframes. A combination of political and economic factors prevents existing parallel and supercomputers from being used in India.

To address the applications needs as well as to grow research and development efforts in both hardware and software, it was decided to build and commercialize a parallel computer with peak performance around 1 GFLOP, and also to develop and support the systems and application software associated with such a computer.

After looking at various possibilities, it was decided that Inmos T800 transputers offered the easiest route for a scalable, flexible, reliable system that would be able to run a variety of applications. A system was designed by grouping the T800s in a cluster of 64 nodes. Each node consists of a T805 transputer and 4 or 16 MBYTES of memory. The cluster contains four 96 × 96 cross-point switch planes. Of the 96 links, most

are used for the compute nodes, but some are for I/O to disks, host interfaces, spares, and 16 are for interconnecting between clusters. A 256-node system (four clusters) was running by mid-1991. By chaining the systems it is possible to build 1024 or larger node machines. Up to 18 hosts can be connected to a 256-node PARAM (the name is both an acronym for Parallel Machine and also Sanskrit for Supreme), which is designed to sit as a back end to a Sun or similar system. At this moment there are over 50 cluster installations within India (Joshi estimates the commercial value to be about US$9M.)

A PARAM board containing four nodes and memory can be replaced with one that also has an i860 with 8 MB memory and a 60 MB/s data transfer mechanism between the i860 and the transputers. The i860s can be viewed either as vector accelerators attached to the transputers (via remote procedure calls), or the transputer's communication links can be used to develop parallel code for the 860s.

CDAC has also built a large and impressive-sounding collection of software. This includes compilers (C and Fortran,) system software, utilities, and tools. Just about everything was done ab initio; Joshi admitted that while economics was a factor, it was also done to learn the ropes and also to satisfy what he called an Indian "obsession" with doing everything themselves. In the applications area Joshi explained that there are some collaborations with Russian scientists. He commented that the well-known Russian strength in theory had overshadowed the fact that they also had real ability in computer implementation and had developed excellent user interfaces for their application software.

In addition to the basic utilities for ordinary and parallel programming, CDAC has visualization tools and a substantial collection of specific applications, including image processing, finite element analysis, digital signal processing, synthetic aperture radar analysis, computational fluid dynamics, auditory spectrograms, logic simulation, protein sequencing, and electron structure. He also emphasized that there was significant work in parallel libraries and parallel numerical algorithms, both of real interest to me. He gave only a few performance figures; one was solving a 1 K $\times$ 1 K linear system (Linpack) on a 64-node cluster using CDAC's Fortran compiler. This ran at 32 MFLOPS, about 82% of the maximum possible speedup from one node, but about half as fast as a careful Occam implementation. CDAC had also obtained about 110 MFLOPS on a 256-node machine with preconditioned conjugate gradient. One of the U.K. attendees asked if these figures weren't low compared with commercially available parallel systems. This question was well intentioned, but it seems to me its answer was essentially irrelevant. PARAM was built to eliminate the need to buy commercial systems and also to develop in-country expertise. As long as India can justify the time and labor costs of the development as opposed to the real financial cost of foreign hardware purchases, and as long as its user base is moderately satisfied with the performance obtained, this kind of activity is both sensible and prudent.

For the future CDAC is going to build a PARAM model based on the new T9000 transputer. In principle, such a system would have TFLOP performance capability. Also faster peripherals will be developed and networking access will be improved as well. CDAC is also thinking about building a 4-8 CPU shared memory system with performance of about 100 MFLOPS. Software activities involve more applications development, and the group is looking at some new areas, including multimedia, parallel databases, animation, and other radar applications. Joshi commented that CDAC was very actively interested in global linkages; this immediately gave rise to comments from several Japanese that they thought there were various opportunities offered by the Japanese government that should be explored.

INVITED PAPERS

"Trends in Massively Parallel Computing," Francis Wray (Parsytec Computer GmbH, Jeulicher Strasse 338, Aachen D-5100, Germany).

"Formal Routes from Specification to Occam," David Crowe and Peter S. Clark (Faculty of Mathematics, The Open University, Milton Keynes, U.K.)

"C-DAC, India's Supercomputing Initiative," Ashok Joshi (C-DAC, India [see text for address]).

"T9000 Updates and Occam 3 (Inmos Ltd., U.K.).

SESSION 1: PARALLEL ARCHITECTURES

"A Scalable Cellular Array Architecture," Paul Cockshott, Paul Shaw, Peter Barrie, and George J. Milne (HardLab, Department of Computer Science, University of Strathclyde, 26 Richmond Street, Glasgow, U.K.).

"Real-time Message Routing with Virtual Cut-through in Transputer

Networks," S.W. Lau (Computer Science Department, University of California, USA [LAU@CS.UCSD.EDU); Francis C.M. Lau (Computer Science Department, University of Hong Kong, Hong Kong [FCMLAU@CSD.HKU.HK]).

SESSION 2: PARALLEL ALGORITHM ON A TRANSPUTER NETWORK (PART 1)

"Gaussian Elimination of Symmetric, Positive Definite, Banded Systems on Transputer Networks," Fida H. Chishti, Anthony. R. Clare and Moe Razaz (University of East Anglia, Norwich NR4 7TJ, U.K.).

"Parallel FFT Algorithms on an Eight-Neighbor Processor Array," Kuninobu Tanno, Toshihiro Takeda (Yamagata Univ., Yonezawa, Yamagata 992 Japan) and Susumu Horiguchi (Tohoku University, Sendai, Miyagi 980, Japan).

"Experimental Evaluation of Node/Variable-Selection and Load-balancing Strategies in Parallel Branch-and-Bound Algorithms for Solving 0-1 Knapsack Problems on a Transputer Network," Toshimasa Watanabe, Satoshi Kajita, and Kenji Onaga (Department of Circuits & Systems, Hiroshima Univ., 4-1 Kagamiyama 1 chome, Higashi-Hiroshima 724 Japan).

SESSION 3: PARALLEL SIGNAL PROCESSING

"The Approach of the Real-Time Underwater Data Transmission System based on Scale-Space Filtering," Kazuyoshi Mori, Shigeki Doi, and Minoru Matsuda (Information Engineering Laborabory, Department of Electronics, Osaka Electro-Communication University, 18-8 Hatsu-cho Neyagawa Osaka 572, Japan).

"An Integrated Car Navigation System using a Single Processor for GPS Signal Processing, Positioning, Map Display, and Reporting," Philip G. Mattos (Inmos Ltd., 1000 Aztec W., Almondsbury, Bristol, BS12 4SQ, U.K.).

SESSION 4: FRAMEWORK FOR PARALLEL IMPLEMENTATION

"Synergetic Computation for Constraint Satisfaction Problems Involving Continuous and Fuzzy Variables by Using Occam, Osamu Katai and Shigeo Matsubara (Department of Precision Mechanics, Kyoto University, Sakyo-ku, Kyoto, 606-01 Japan [D52754@JPNKUDPC.BITNET]), Hiroshi Masuichi (Fuji Xerox Co. Ltd., Japan), Masaaki Ida, Tetsuo Sawaragi, and Sosuke Iwai (Kyoto University, Japan).

"A Framework for Multiagent Planning and a Method of Representing its Plan Integration," Takashi Nishiyama (AI Group, Matsushita Electric Works, Ltd., 1048 Kadoma, Osaka 571, Japan [TAKASHI@AI.NEW.MEI.CO.JP]), Osamu Katai, Tetsuo Sawaragi, Sosuke Iwai, and Tadashi Horiuchi (Kyoto University, Japan)

"Reduction by Message Passing and Its Implementation on Transputer Network," Hiroshi Nunokawa and Shoichi Noguchi (Tohoku University, Japan [address above]).

SESSION 5: PARALLEL ALGORITHMS ON A TRANSPUTER NETWORK (PART 2)

"Development of the Parallel Particle-in-Cell Code on a Transputer Network," Masami Matsumoto (Yonago National College of Technology, 4448 Hikona, Yonago, Tottri 683, Japan).

"Development of the Parallel Modified Lax-Wendroff Algorithm," Akitsugu Takeuchi, Hideharu Handa, Takeshi Sainoh, Masaru Sakamoto, Kenji Tamon, and Yukinori Tanaka (Yonago National College of Technology, Japan) and Kazunari Shibata (National Astronomical Observatory, Japan).

"Logic Simulation Algorithm on Network of Transputers," S. Sundaram and L. M. Patnaik (Indian Institute of Science, Bangalore, India).

SESSION 6: TRANSPUTER SYSTEM

"Full Digital Control of Power Electronics Converters Using Transputers," L. Matakas, Jr. E. Masada, and T. Morizane (Department of Electrical Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan) and S. Koseki (Hitachi Works, Japan).

"A Modular, High Speed Transputer-based Data Acquisition System," P. M. Neal, M. L. G. Oldfield, and S. A. Cameron (Department of Engineering Science, University of Oxford, Parks Road, Oxford OX1 3PJ, U.K.).

INSTITUTE FOR NEW GENERATION COMPUTER TECHNOLOGY (FIFTH GENERATION COMPUTING) 1992 (FINAL CONFERENCE)

A brief description of the Fifth Generation Computer System, 1992 (final) conference, and an evaluation are given.

by David K. Kahaner

I have written several reports on the Fifth Generation Computer Systems (FGCS) project, and its associated research institute, Institute for New Generation Computer Technology (ICOT). See for example, [icot.kl1, 28 Feb 1992].

During the week 1 to 5 June the 1992 FGCS international conference was held, and almost 2,000 people attended. I am hoping to receive detailed reports from several attendees and will distribute these when they arrive, but in the meantime I will summarize some of the important developments very briefly.

The FGCS'92 conference was one of the best planned and executed international meetings that I have ever attended. The materials, lectures, and demonstrations have been organized and implemented with great care and preparation. The conference materials included a two-volume proceedings, complete copies of all the keynote and invited speeches, a detailed (37 page) outline of the history of the project, a complete and detailed explanation of more than twenty demonstrations, and a list and explanation of all the ICOT software. The printed material, over 2,000 pages, is in English.

It is not possible to fully summarize in this report the FGCS project. Dr. K. Fuchi, who runs the research center in Tokyo (ICOT) gave an excellent keynote speech. I was sufficiently impressed to produce a copy for inclusion with the report, below. It is both readable and interesting, and I urge you to read it.

I discussed some of my thoughts about the project with other visiting Westerners. The comments below are a quick summary of the general feelings expressed to me, as well as my own.

When FGCS was established in the early 1980s, its hopes were to use two new ideas together. First, the concept of logic programming, best known to the computing world through the languages of Prolog and Lisp, to solve very difficult computing problems of nonnumerical type. Second, parallel processing to provide the computational power to tackle the huge computational needs that logic programming would require. During the ten-year period of the project, the Japanese government spent more than 50 billion Yen (over US$300M). ICOT has had almost 200 Japanese researchers who rotate back to their home institution every 3 to 4 years. At the moment there are about 100 researchers at ICOT, almost all under 35 years old. About 75 non-Japanese researchers from 12 countries have participated in FGCS, and seven have worked at ICOT for one year or more.

At the beginning of the project, Japan's status in terms of computer science was very low, in contrast in the West, project descriptions were greeted with a combination of derision (problems are too difficult for us, no less than the Japanese, etc), and panic (if the Japanese solve these problems before we do, they will control the world's technology for decades, etc). No matter what the results, Western scientists would be able to say "we told you so". Towards the latter part of the project, the general view in the West has been that its goals have not been met. I have consistently stated in these reports, and will do so again, that my own opinion is that the impossibly high expectations claimed for FGCS were Western, and not the same as those claimed by the Japanese. The project needs to be judged against its own claims, rather than ours. Dr. Fuchi, below, makes a similar comment.

While FGCS was not another "sputnik," it had many significant accomplishments. The world has changed in ten years. The key role played by logic programming is seen by many to be reduced. Nevertheless, logic programming systems developed at ICOT are probably the best in the world. A variety of parallel computers have been built to test ideas, and some of these experimental machines are as interesting as parallel computers anywhere. The latest appears on the verge of achieving its goals of 10^8 logical inferences per second. Whether that speed can be attained or sustained in a real application remains to be seen. Large numbers of young Japanese have been trained in the ideas of symbolic computation, software and parallel computing, and there is probably as much or more expertise within Japanese companies on these topics as within any Western counterparts. FGCS provided both money and focus to successfully lubricate the start-up of a knowledge processing industry in Japan. The basic research from Japan in theorem proving and related areas is comparable to that in the West. A very different situation from that of ten years ago. Everyone I spoke to agreed on the major role FGCS played in the infrastructure of Japanese computer science. Also, most Western attendees were more impressed than they expected to be with the results that they heard about.

On the negative side is a lack of real applications. ICOT has developed, as the demonstrations showed, a significant number of interesting small (prototype) applications. These are running on ICOT's parallel hardware and show good speedups, which approach linear in a few cases. Perhaps ICOT should have focused on a few big applications to drive the project; these always help channel and define the problems that really need to be solved rather than those that the developers are interested in solving. Perhaps ICOT hoped that industry would jump in. In fact they did not. And, given the size of the FGCS project and the number of computer makers that participated by building hardware and sending their researchers, the direct impact of FGCS on Japanese industry has been low. We repeatedly asked responsible industrial officials about the impact, and consistently got a polite "not much". It may be too early. Dr. Fuchi, below, states that we will have to wait another five years to see realistic applications. Also, ICOT developed hardware and software is unused and unusable outside of Japan, and not as much inside Japan as the ICOT people would like. A unique language and computer operating system have been developed. Presently these need to be run on special hardware, although ICOT is studying the possibility of moving the software to more standard Unix workstations.

To get more users, and also to encourage more international cooperation, MITI (Ministry of International Trade and Industry), has announced that all the ICOT developed software will be available free of charge in source form, without any restrictions as to use, modification, copying, expanding, etc. Of course no warranties are associated with such software. This amounts to over 70 large programs and includes the parallel operating software, parallel logic programming language, and all the software demonstrated at the conference.

Actually, this concept has been discussed for about a year, but MITI has now made it official. The problem of on what machines to run the programs still exists, but it is an intelligent step by MITI nevertheless; without it the intellectual products of FGCS would likely remain unused outside of Japan. This new policy only applies to the software developed for this project. But statements by MITI about "promote the advancement of the technologies of knowledge information processing and parallel processing" suggest that it will be applied to the Real World Computing (RWC) project, MITI's new ten year project.

Concerning the demonstrations, I should mention that these were exceptionally well done. Within ten booths, every major ICOT software product was shown, with mini-lectures, hands on, video tapes, etc., with a good combination of overview and detail. These included the following:

- Parallel inference systems,
- Diagnostic and control expert system based on a plant model,
- Experimental adaptive model-based diagnostic system,
- Case-based circuit design support system,
- Experimental parallel hierarchical recursive layout system,
- Parallel cell placement experimental system,
- High level synthesis system,
- Cooperative logic design expert system,
- Parallel LSI (large-scale integration) router,
- Parallel logic simulator,
- Protein sequence analysis program,
- Model generation theorem prover,
- Parallel database management system,
- Knowledge representation language,

- Parallel legal reasoning system,
- Experimental motif extraction system,
- Concurrent program development system,
- Parallel constraint logic programming system,
- Experimental system for argument text generation,
- A parallel cooperative natural language processing system, and
- Experimental discourse structure analyzer.

As part of the program materials for this conference, we were given a questionnaire. Results of the questionnaire will influence the future of the project. Some downsizing will occur, although staff will be retained to deal with the issue of distributing software. Dr. Fuchi mentioned that the topic of parallel information processing is still considered an important topic and might be the subject of another national project.

Launching the New Era

Dr. Kazuhiro Fuchi, Director, Research Center Institute for New Generation Computer Technology (ICOT) 4-28, Mita 1-chome, Minato-ku, Tokyo 108, Japan (Presented as a keynote speech at the FGCS 1992 Conference, June 1992, Tokyo).

(In quotation marks below are remarks made by Dr. Fuchi during the presentation of his talk. Whenever names are given of ICOT scientists, these are usually accessible via electronic mail by addressing in the form 'last-name@icot.or.jp', such as 'kurozumi@icot.or.jp'.)

"Thank you for coming to FGCS'92. As you know, we have been conducting a ten-year research project on fifth generation computer systems. Today is the tenth anniversary of this project and marks the founding day of our research center.

The first objective of this international conference is to show what we have accomplished in our research during these ten years.

A variety of innovative studies, in addition to our own, have aimed at future generations of computers and addressed the future of information-processing technologies. These projects are currently in progress in many parts of the world. Another objective of this project is to offer an opportunity for researchers involved in FGCS-related advanced research to present the results of their work and to exchange ideas.

I constantly use the phrase "parallel inference" as the keywords to simply and precisely describe the technological goal of this project. Our concept holds that parallel inference technology will provide the core for those new technologies in the future—technologies that will be able to go beyond the framework of conventional computer technologies.

During these ten years I have tried to explain this idea whenever I have had the chance. One obvious reason why I have repeated the same thing so many times is that I want to make its importance known to the public. But I have another less obvious reason.

When this project started, an exaggerated image of the project was engendered. This image seems to persist even now. For example, some people said that we were trying in this project to solve in a mere ten years some of the most difficult problems in the field of artificial intelligence (AI), or to create a machine-translation system equipped with the same capabilities as humans.

In those days, we had to face criticism based upon the false impression that it was a reckless project trying to tackle impossible goals. Now we see criticism from inside and outside the country claiming that the project has failed because it has been unable to realize those grand goals.

The reason why such an image was born appears to have something to do with FGCS'81—a conference we held one year before the project began. At that conference we discussed many different dreams and concepts. The substance of those discussions was reported as sensational news all over the world. Any vision with such ambitious goals, however, can never be materialized as a real project in its original form. If a project is started in accordance with the original vision, it cannot be managed and operated within the framework of an effective research scheme. Therefore, our plans had become much more modest by the time the project was launched. For example, the development of an application system, such as a machine-translation system, was removed from the list of goals. It is impossible to complete a highly intelligent system in ten years. It requires a preliminary development stage to enhance basic studies and to improve computer technology itself. We decided that we should focus our efforts upon this preliminary stage. There was, also, another reason. At that time in Japan, some companies had already begun independently to develop realistic, low-level machine-translation systems, and developmental competition was sure to ensue. A large part of our pattern-recognition research was also eliminated, because a national project called "Pattern Information Processing" had already been conducted by the Ministry of International Trade and Industry for ten years. We also found that the stage of the research did not match our own.

Does all this mean that FGCS'81 was deceptive? I do not think so. First, in those days, a pessimistic outlook predominated concerning the future developments of technological researches. For example, there was a general trend that research on artificial intelligence would be of no practical use. In that sort of situation there was considerable value in maintaining a positive attitude toward the future of technological researches whether this meant ten years or fifty. I believe that this was the very reason why we received remarkable reactions, both positive and negative, from the public.

Second, the concept of parallel inference was presented in a clear-cut form at FGCS'81. A diagram can be seen in Fig. 1. This diagram was the one I used for my speech at FGCS'81. The draft for this was completed in 1980, but I had come up with this idea four years earlier. After discussing the concept with my fellow researchers for four years, I finally completed this diagram.

Here, you can clearly see our concept that our goal should be a parallel inference machine. [The figure that Dr. Fuchi mentions clearly shows that the program goal is to build a parallel inference machine.]

I would appreciate it if you would compare this diagram with our planning for the final stage of this project, which Deputy Director Kurozumi will show you later. I would like you to compare the original structure conceived 12 years ago and the present results of the project so :hat you can appreciate what has been accomplished and criticize what is lacking or what was immature in the original idea.

Some people tend to make more of the conclusions drawn by a committee than the concepts and beliefs of an individual. It may sound a little bit beside the point, but I have heard that there is a proverb in the West that goes, "The horse designed by a committee will turn out to be a camel."

The preparatory committee for this project had a series of enthusiastic discussions for three years before the project's launching. I thought that they were doing an exceptional job as a committee. Although the committee's work was great, I must say that the plan has become a camel. It seems that their enthusiasm has created some extra humps.

This is not the first time I have expressed my opinion about this issue. I have, at least in Japanese, been saying this in public for the past ten years. I think that I could have been discharged at anytime my opinions were inappropriate.

As the person in charge of this project, I have pushed my opinion in line with the parallel inference policy based upon my own beliefs. Although I have been criticized as still being too ambitious, I have always been prepared to take responsibility for that.

Since it is a national project, it goes without saying that it should not be controlled by one person. I have had many discussions with variety of people for more than ten years. Fortunately, the belief has not remained just one person's belief but has become a common belief shared by many researchers and research leaders involved in the project.

Assuming that this project has proved to be successful, as I believe it has, this fact is he biggest reason for its success. For a research project to be successful, it needs a favorable work environment that meets many conditions [including financial]. But what is most important is that the research group involved has a common belief and a will to reach its goals.

So much for introductory remarks. I wish to outline, in terms of parallel inference, the results of our work conducted over these ten years. I believe that the remarkable feature of this project is that, by focusing upon one language, it has succeeded in experimenting with the development of hardware and software on a large scale, based upon that language.

From the beginning, we envisaged that we would take logic programming and give it a role as a link that connects the highly parallel machine architecture and the problems to be solved concerning applications and software. Our mission was to find a programming language for parallel inference.

A research group led by Deputy Director Furakawa was responsible for this work. As result of their efforts, Ueda came up with a language model, GHC, [Guarded Horn Clause] at the beginning of the intermediate stage of the project. The precursors to this were such as Parlog and Concurrent Prolog. He enhanced and simplified them to make this model. Based upon GHC, Chikayama designed a programming language called KL1.

This KL1, a language derived from the logic programming language concept, provided a basis for the later half of our project. Thus, all of our research plans in the final stage were integrated under a single language, KL1.

For example, we developed a hardware system, the Multi-PSI, at the end of the intermediate stage. We demonstrated it at FGCS'88. After the conference we made copies, and since then we have used them as the infrastructure for software research.

In the final stage, we made a few PIM prototypes, a "parallel" inference machine that has been one

of our final research goals on the hardware side. These prototypes are being demonstrated at this conference.

Each prototype has a different structure including an internal network architecture, and each machine is a subject of research. Looking from the outside, however, all of them are KLl machines.

Division Chief Uchida and Laboratory Chief Taki will show you details on this later. What I want to emphasize here is that all of these machines, including their internal chip designs even, are designed with the assumption that KL1, a language equivalent to other very high level languages, is a machine language.

On the software side, our research topics were also integrated under the KLl language. All the application software and basic software, including operating systems, were to be written in KL1.

We demonstrated an operating system called PIMOS (parallel inference machine operating system) at FGCS'88, which was the first operating system software written in KL1. At that point, it was still immature. It has been improved since then, and the fully matured version of PIMOS securely backs the demonstrations being shown at this conference.

Details will later be given by Laboratory Chief Chikayama, but I wish to emphasize that not only have we succeeded in writing software as complicated and huge as an operating system entirely in KL1, but also that we have proved through our own experience that KLl is much more appropriate than conventional languages for creating the voluminous software required for an operating system.

One of the major challenges in the final stage was to demonstrate that KLl is effective not only for basic software, such as operating and language-processing systems, but also for a variety of applications. As Laboratory Chief, Nitta will report later. We have been able to demonstrate KLl for various software issues including LSI-CAD, genetic analysis, and legal inference. These are closely related to issues in the real world and have a scale nearly sufficient for practical use. But, again, what I wish to emphasize is that the objective of those developments has been to demonstrate the effectiveness of parallel inference.

In fact, in the first stage we tried this type of approach to develop a project focusing upon one particular language, although it was a stage in which research was conducted using sequential techniques. We used ESP, an expanded version of Prolog, as a basis.

Assuring that ESP could play a role as KLO, a sequential personal inference machine called PSI was designed as hardware. We decided to use the PSI machine as a workstation for our research. Some 500 PSIs, including modified versions, have so far been produced and used in the project.

SIMPOS, the operating system designed for PSI, is written solely in ESP. In those days, this was one of the largest software volumes written in a logic programming language. Up to the intermediate stage of the project, we used PSI and SIMPOS as the infrastructure to conduct research on expert systems and natural language processing. [Dr. Fuchi mentioned that there have been criticisms of this approach.]

Our project, though it is conducted on a large scale, is still considered basic research. Accordingly, it is supposed to be conducted in a free, unrestrained atmosphere so as to bring about innovative results. Some of you may be wondering whether above policy restrains the freedom and diversity of research? But this is also based upon my, or our, philosophy. I believe that research is a process of "assuming and verifying an hypothesis." If this is true, the hypothesis must be as pure and clear as possible. If not, you cannot be sure what you are trying to verify.

Another thing is that we had a strong belief that our hypothesis had sufficient scope for a world of rich and free research. Even if the hypothesis were restrained, we believed that it was a creative constraint.

I would be a liar if I were to say that there was no resistance among our researchers when we decided upon the policy. KLl and parallel processing were a completely new world to everyone. It required a lot of courage to plunge headlong into this new world. But once everyone overcame the psychological barrier, the researchers set out to create new parallel programming techniques, one after another.

Among the many other results we obtained in the final stage was the development of a fast theorem-proving system, or prover. Details will be given in Laboratory Chief Hasegawa's report. I think that this research will lead to the resurrection of theorem-proving researches. This prover is also used in the inference engine of our legal inference system.

The research on programming languages has not ended with KL1. For example, a constraint logic programming language called GDCC has been developed as a language higher than KL1. We also have a language called Quixote.

From the beginning of this project, I have advocated the idea of integrating three types of languages—logic, functional, and object-oriented languages and two worlds: the programming world and the database world. In the Quixote language, this idea has been materialized. It is something we call a deductive

object-oriented database language. (My discussions with researchers at the conference suggested that Fuchi's view of object oriented languages is relatively recent.)

Another language, CIL, was developed by Mukai in the process of studying natural-language processing. CIL is a semantic-representation language that is also designed to deal with situation logic. CIL is incorporated into Quixote in a natural form. Quixote therefore has the characteristics of a semantic-representation language. As a whole, it shows one possible future form of knowledge-representation languages.

More details, along with the development of a distributed parallel database-management system, Kappa-P, will be given by Laboratory Chief Yokota.

Thus far I have outlined, albeit briefly, the final results of our ten-year project. Recalling what I envisaged ten years ago and what I have dreamed and hoped would materialize for 15 years, I believe that we have achieved as much or more than what I expected, I am quite satisfied.

A national project is not performed for mere self-satisfaction. The original goal of this project was to create the core of next-generation computer technologies. Many different elemental technologies are required to materialize future computers or tomorrow's information processing. Although it is impossible for this project alone to provide all of the elements, we are proud to be able to say that we have created the core, or at least provided an example.

The results of this project, however, cannot be commercialized as soon as the project is finished, which makes the fact that it is a national project more meaningful. I estimate that we need another five years, which could be called "a maturing period for the technology", for the results to actually take root in society. I had this prospect in mind at the beginning of this project ten years ago, and have kept relating it in public right up until today, but I still have the same idea now that our project is nearing its end.

It often happens that there is a gap of ten or twenty years between the basic research stage of a technology and the day it appears in the business world. UNIX, C, and RISC, the technologies involved in the popular trend toward downsizing, are good examples of this.

From the beginning of our project, we tried to think of technologies in the distant future that would go beyond these.

(Dr. Fuchi commented that many researchers are of the opinion that Japanese industry has already caught up with ICOT research.)

A movement toward parallel computers has been gaining momentum as a technology lead into the future. But skeptical opinions were dominant ten years ago. The situation was not very much different five years ago, and skepticism still remains. But the trend seems to be rapidly changing. In the background, there exists the fact that it is becoming easier to make a parallel machine by placing many chips together, because semiconductors technology constantly makes progress.

In most cases, people still focus upon supercomputers for scientific and engineering use, and their ideas tend to be (naive and) vague regarding the software side (sic!). Despite this a new age is dawning.

The software issue might not be a big problem as long as scientific and engineering computations remain merely scaled-up matrix calculations (and maybe Fortran would suffice), but software will certainly become a great problem in the future. If this problem could be solved, would it allow us to deal with massive problems that have complicated overall structures? If this is realized, we would have something like a general-purpose capability that is not limited to the range of scientific computations. We might then be able to replace the mainframe computers we are using now.

The scenario mentioned above is one possibility leading to new, future computers that are equivalent to current mainframes. If you think about what type of technology will then be required, the answer should be the parallel inference technology which we have been pursuing.

I will not press this idea upon you. But I anticipate that if anybody starts research without knowing our ideas, or if that research is based upon a philosophy that is quite different from ours, after many twists and turns that person will reach more or less the same concept as us with only small differences such as different names.

It may be valuable for researchers to be independent from what has already been done, for them to struggle through a process of research by themselves, and to find that they have followed the same course as somebody else. But it is more efficient to build upon what has been done in this FGCS project and divert energy to moving forward from that point.

This project will be finished at the end of this year. As for "maturation of the parallel inference technology", I think we will need a new pattern for our research activities. There is a concept called "distributed cooperation" in computation models. I expect that, like in that kind of pattern, the seeds generated in this project will spread both inside and outside the country and sprout in many different parts of the world.

For this to be realized, the results of this project must be freely

accessible and available worldwide. This means that it is essential to disclose our accomplishments, for example in the software area including the source codes, and to make them "international common public assets."

We have tried for ten years to encourage international exchange in this project. As a result we have enjoyed opportunities to meet with many researchers involved in advanced studies in various parts of the world. They have given us much support and cooperation. This project could not have been completed without this generous support and cooperation.

In that regard, and also considering that this is a Japanese national project that aims at making a contribution, though a small one, toward the future of mankind, we believe that we are responsible for leaving our research accomplishments as a legacy to future generations and to the international community in the most suitable form.

Although this project is about to end, the end is just another starting point. The advancement of computers and information-processing technologies is closely related to the future of human society. For the purpose of launching a new age, I fervently hope that the circle of those who share our passion for a bright future will continue to expand. Thank you.

PROGRAMMING LANGUAGES FOR MACHINE TOOLS CONFERENCE, 24-26 JUNE 1992 TOKYO, JAPAN

The 1992 PROLAMAT (Programming Languages for Machine Tools) Conference, held 24-26 June, 1992, in Tokyo, Japan is summarized. The major theme of this conference was "Human Aspects in Computer Integrated Manufacturing."

David K. Kahaner and Stephen Lu

With many thanks, I acknowledge that the analysis sections of this report were written by:

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The report also contains a description of seven technical tours extracted from the conference announcement. Prof. Lu did not participate in these tours but reports that those who did were impressed. Also included is a list of titles and authors of all the papers presented. These papers are also available in the published proceedings.

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INTRODUCTION

The PROLAMAT (old abbreviation: Programming Languages for Machine Tools) Conference is an internationally well appreciated technical event for demonstrating and evaluating activities and progresses in the fields of information processing for discrete manufacturing. The conference is sponsored by the International Federation for Information Processing (IFIP) and is usually held once every three years in different IFIP member's countries. The 1992 conference was organized by the WG3 (Working Group 3) for "Computer-Aided Manufacturing" of TC5 (Technical Committee 5) for "Computer Applications in Technology". The cochairpersons of this year's conference were Professor F. Kimura of the University of Tokyo, Tokyo, Japan, and Dr. G. J. Olling of Chrysler Motors, Highland Park, Michigan, USA. The International Program Committee consists of 38 members from 18 different countries, including several Asian countries such as Korea, Japan, and China. After an exceptional break of four years, PROLAMAT 92 was the eighth conference and the first one held in Japan. JSPE (Japan Society for Precision Engineering) and IPSJ (Information Processing Society of Japan) were conference cosponsors.

Although the original intent of PROLAMAT was focused on software development for machine tools, as indicated by its old abbreviation, the current scope of the conference includes the whole area of advanced computer technologies (particularly the software technology) for discrete manufacturing. For example, some of

the major topics of the past PROL-AMAT conferences are:

— Advanced Manufacturing Technology
— Advances in CAD/CAM
— Software for Discrete Manufacturing
— Software in Manufacturing

An interesting evolution over the past decade is that the conference has been expanded from Computer Aided Manufacturing (CAM) to Computer Integrated Manufacturing (CIM). More emphasis is placed on various system integration issues related to product design, planning, and manufacturing activities through new computer and communication technologies. The conference includes papers and presentations for basic research and advanced applications from academia and industry.

The main theme of this year's conference was *Human Aspects in Computer Integrated Manufacturing.* Computer-based systems are now being widely used for manufacturing automation. Many routine jobs in production can now be carried out automatically without much human intervention. Regardless of this increasing degree of computer automation, there still exist important tasks for which human intelligence and physical actions are definitely required. Therefore, an important goal of advanced manufacturing systems is to integrate computers with humans, rather than to isolate humans from automated systems. However, as computer automated systems become more sophisticated, the role of humans in these systems becomes harder to define and manage. It is important to investigate the proper balance and integration schemes so that humans and computers can work in harmony, realizing a productive working environment for engineers that could amplify their original ability and creativity.

This year's conference was held at the Surugadai Memorial Hall at the Chuo University in Tokyo from June 24 to 26, 1992. It brought together almost 221 scientists and engineers from 19 countries. The participant distribution was as follows:

Country	No. of Participants
Byelorusia	1
Canada	1
Estonia	1
Finland	4
France	9
Germany	10
Hungary	1
Italy	7
Japan	144
Korea	12
Netherlands	2
Norway	2
People's ROC	4
Philippines	4
Singapore	1
Slovenia	1
Sweden	4
United Kingdom	1
USA	12

The Japanese attendees accounted for about 65% of the total participants. About 75% of the participants comes from Asian countries. The distributions between industry and university participants are about 62% and 38% respectively.

CONFERENCE SUMMARY

The three-day program was organized into one Keynote Speech Session, one Invited Speech Session, six Organized Paper Sessions, and 16 Regular Paper Sessions. Total of 60 technical papers from 13 different countries were presented at the conference.

The two keynote speeches were:

1. *Amalgamation of Human Intelligence with Highly Automated Systems*—An Approach to Manufacturing Structure in the 21st Century in Japan, Institute of Technology.

2. *FMS*—A Complex Object of Control, by Professor J. Peklenik of University of Ljubljana in Slovenia.

In his presentation, Professor Ito explained the trends of the human-intelligence-based manufacturing, and summarized possible configurations and required functions of one of its variants—the Thought-Based Manufacturing Systems (THOMAS). He discussed two research issues that will play important roles in THOMAS: culture of manufacturing and understanding of deep knowledge and flair of mature engineers to manufacture human sensitivity-oriented and art-like products. The presentation illustrated some interesting concepts for future manufacturing enterprise. Some of these concepts seem to be similar in spirit to those being proposed in the western world; but, because of language translation differences, comparisons are hard to draw.

Professor Peklenik introduced a new concept in viewing manufacturing activities/objects from the system control point of view, and, hence, allowing a more rigorous approach to model flexible manufacturing systems (FMS). He outlined the basic assumptions, the system control models, and explained the requirements for such an approach. Several examples were given, which helped to understand how this approach can be applied to practical cases in the factory. It is clear that as more complexity and intelligence are being added to modern manufacturing systems, more powerful analysis approaches, like the one introduced by

Professor Peklenik, will be essential for research and development efforts in this area.

The two invited speeches were:

1. *CAD/CAD/CAM Perspectives at Chrysler Corporation*, by Dr. G. Olling of the Chrysler Corporation.

2. *The Roles of Man and Computer in CIM Systems*, by Dr. Toshio Ito of Mitsubishi Electric Corporation.

To complement the two keynote speeches from university researchers, the two invited speakers' presentations were more industrial oriented. Both focused on the main issues of computer automation and how humans should effectively fit into those highly automated systems. They gave detailed case studies from their respective companies to illustrate the impact of automation on organization and human productivity.

The six organized paper sessions were focused on the following preselected technical areas:

- Architecture and Methodologies to Design Advanced and Integrated Manufacturing Systems, organized by G. Doumeingts of France
- Shortening of Development Time, organized by F.-L Krause of Germany
- Product Modeling and Data-Driven Applications in Design and Manufacturing, organized by T. Kjellberg of Sweden
- Computer Aided Process Planning in CIM Environment, organized by D. Kochan of Germany
- Sensor-Based Intelligent Manufacturing, organized by Y. Hatamura of Japan
- Scheduling in CIM Environment, organized by A. Rolstadas of Norway.

These areas gave a very good description of the technical scope of the rest of the conference discussions. Total of 19 papers from known researchers in the area were invited to be included in these organized sessions. Unlike typical paper sessions, each organizer tried to create a unified technical theme among paper presentations in each session, which greatly helped understanding the the state-of-the-art of technology. These organized sessions were highly worthwhile and well attended, adding much to the total success of the conference.

The regular paper sessions were for papers submitted to the conference through a formal Call for Paper Announcement and went through the normal paper review procedures. The topics of these papers covered a very wide range of CIM areas. Although the conference organizer tried to group them according to the following 16 broad topics, a cohesive theme for each paper session, as is the case in most conferences, is difficult to obtain:

- Design Theory and Methodology
- Product and Process Modeling
- Feature Modeling
- Geometric Modeling
- Engineering Simulation and Planning
- Rapid Prototyping
- Human Roles in CIM Systems
- CIM Systems Development Support
- Manufacturing Automation
- Operation Planning for Machining
- Machining Systems
- Scheduling in FMS
- FMS Design and Operation
- FMS Design and Operation
- Advanced Manufacturing Systems
- Advanced Manufacturing Systems.

Overall, the PROLAMAT '92 was a successful conference. The conference chairpersons, Professor F. Kimura and Dr. G. Olling, did a very good job in planning and organizing this international event. Members of the local organizing committee and support staff, led by Professor Kimura, worked very hard to ensure a smooth execution of conference plans. The social events (with invited speeches) were very enjoyable and successful. There were many interesting technical subjects in the areas of CIM been presented and discussed by researchers and practitioners around the world during this conference. The conference proceedings is professionally published by North-Holland as IFIP Transactions, Volume B-3 (ISSN 0926-5481). The conference, proceedings, and discussions firmly established a solid foundation for manufacturing software development that is the long-lasting goal for PROLAMAT.

PRE- AND POST-CONFERENCE TECHNICAL VISIT/TOUR

Tours and visits to the following Japanese factories were arranged by the conference organizer·

1. *Fanuc*—Head Office and Plants-Oshino-mura, Yamanashi-ken. Fanuc is a comprehensive manufacturer of factory automation equipments. Its wideranging factory automation (FA) products integrate basic technologies, in industrial computers, control motors, etc. At the same time Fanuc is also a major producer of electromechanical products based *on FA technologies that include* industrial robots, plastic injection molding machines, and CNC wire-cut EDM. Fanuc headquarter is

located at the foot of Mt. Fuji, in a wonderful natural environment. The electronics factory, control motor factory, laser factory, machining factory, robot assembling factory, injection modelling machine factory and system factory are settleo here.

2. *Nissan Motor*—Zama Plant—Zama-shi, Kanagawa-ken. The Zama plant is one of Nissan's nine major domestic manufacturing facilities. The plant was the world's first automobile plant to employ body assembly robots and is among the key car assembly facilities of Nissan. The plant exports knockdown kits and provides technical assistance for Nissan's overseas operations. It also maintains a machine and tool plant where it designs and manufactures press dies, jigs, robots, and other special purpose machinery. We also visited fully automated manufacturing lines.

3. *Makino Milling Machine*—Atsugi Plant—Aiko-gun, Kanagawa-Ken. Makino developed Japan's first numerically-controlled milling machine, machining center, adaptive control system and automatic die and mold machining system. The wide range of machines available is helpful in selecting machines best suited for a job. At Atsugi plant, an advanced FMS is operating. At every stage of the production process, all the employees showed scrupulous dedication to machine building in the micron precision, which is the cornerstone of the reputation for quality. We visited a large machine assembly line and FMS factory.

4. *Matsushita-Seiko*—Kasugai Plant—Kasugai-shi, Aichi-ken. Matsushita Seiko has focused on technologies centered on wind and air. The inner-rotor-type condenser motor, with direct winding from outside, is produced by means of fully automatic machines that enable 24-h unmanned production and further eliminate quality instability caused by manual operations, ensuring steady high-quality production. The production systems of this condenser motor, which suggests the future course of production, enables high productivity and steady high quality in every country.

5. *Yamazaki Mazak Minokamo*—Minokamo-shi, Gifu-ken. The plant consists of FMS machining lines capable of performing all processes in completely unmanned operation, a high precision sheet-metal FMS that can finish all processes from design to assembly in only five days, and a material handling system using a 22,000 rack automatic storage and retrieval system and AGVs to link the material center, the FMSs, and the assembly area. This plant constantly produces products at the leading edge of technology, such as the developed lathe based on completely new production concepts, and a series of ultra-high-speed CNC lathes.

6. *Toyota Motor*—Motomachi Plant—Toyota-shi, Aichi-ken. The Motomachi plant is one of Toyota's main automobile production facilities. This plant contains divisions for the design and manufacture of stamping dies for automobile bodies. (In these divisions, a CAD/CAM method is used, and automobile bodies are developed from the design to the machining of the die face, based on consistent numerical data.) It can be seen how a series of the processes involved in automobile body development greatly contribute to shortening lead time and improving the quality of automobile bodies. We visited the continuous year-round flexible production system for machining stamping dies.

7. *Nippondenso*—Kota Plant—Nukata-gun, Aichi-Ken. Nippondenso develops, designs, and manufactures its own production equipments and flexible manufacturing systems, including automated mass-production lines for high-speed assembly, flexible and automated production lines capable of finishing a wide range of products in random order and easily adaptable to model changes. They are currently installing plantwide an automation system through which production lines will be directly linked to production control and quality control systems. We visited an automated assembly line for hybrid IC regulators and a production line for monolithic integrated circuit.

Stephen C-Y. Lu has a B.S. degree from the National Taiwan University in Taiwan, M.S. and Ph.D degrees from the Department of Mechanical Engineering and the Robotics Institute of Carnegie-Mellon University, U.S.A, where he is currently a tenured full Professor. Dr. Lu is a Research Professor of the Beckman Institute and a Faculty Associate in the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign (UIUC). He is the founder and current Director of UIUC's Knowledge-based Engineering Systems Research Laboratory which pioneers in the areas of AI-based approaches to advanced engineering automation.

Dr. Lu's research interests are in the development of artificial intelligence (AI). He has published over 140 technical papers, reports, chapters, and books.

Dr. Lu has received numerous awards. In 1990 he was appointed as a University Scholar for his excellent contributions to scholarly activities. Recently he was awarded a Fullbright Scholarship in the Senior Research Professor category and an Alexander von Humboldt Research Award for Senior U.S. Scientists to perform research at the Production Technology Centre (PTZ) in Berlin, Germany.

INTERNATIONAL NETWORKING CONFERENCE, INET'92, KOBE JAPAN, 15-18 JUNE 1992

Summary of INET'92, The International Networking Conference, sponsored by the Internet Society, held in Kobe Japan, 15-18 June 1992. Some related comments about the Real World Computing network.

by David K. Kahaner

This was the most international conference I have ever attended.

More than 600 participants, including over 350 representing 70 countries, attended the INET'92 conference held in Kobe Japan. (Most of the attendees spoke the language of networking specialists, sentences full of uucp, TCP/IP, X.25, etc., rather than end users, but there were also a few participants who just wanted to get a sense of what was going on.) This was the first official conference of the newly formed Internet Society. INET is the successor to the Academic Networking Workshops, which were a series of informal, invitation-only international workshops that began in London in 1982.

WHAT IS THE INTERNET?

In 1973, the U.S. Defense Advanced Research Projects Agency (DARPA) initiated a research program to investigate techniques and technologies for interlinking packet networks of various kinds. It was called the Internetting Project, and the family of networks which emerged from the research was known as the "Internet." The suite of protocols that were developed over the course of this research effort became known as the TCP/IP Protocol Suite, after the two initial protocols developed, Translation Control Protocol (TCP), and Internet Protocol (IP). Much of the support for the Internet community has come from the U.S. government, since the Internet was originally part of a federally-funded research program and, subsequently, has become a major part of the U.S. research infrastructure. However, during the late 1980s, the population of Internet users and networked constituents expanded internationally and began to include commercial facilities. Today, the bulk of the system is made up of private networking facilities in educational and research institutions, businesses, and government organizations across the globe. Internet now reaches 107 countries, five-thousand networks with almost one-million hosts and an estimated five-million users. The host computers are almost all running the TCP/IP protocols (90%), with the remainder running uucp, Fido Net, and Bitnet. Since 1989, the Internet system began to integrate support for other protocol suites into its basic networking fabric. Presently, the emphasis is on multiprotocol interworking, and in particular with the integration of the Open Systems Interconnection (OSI) protocols. (Having said that, it should be noted that OSI has not been too successful in Japan although there has been significant effort expended by the government; references to OSI at INET'92 brought consistent chuckles from the Japanese audience. My guess is that it is too early, but that the OSI bandwagon will continue to role on here.)

The Internet Society is the professional organization, with about 1000 members, devoted to promoting growth of the Internet by a combination of technical support, coordination, and forums. Various other organizations are associated with Internet, including the Coordinating Committee for International Networks (CCIRN) Corporation for National Research Initiatives (CNRI) EDUCOM, and the Internet Activities Board (IAB) suborganizations record and register Internet information, provide central allocation of

network and autonomous system identifiers, and provide central maintenance of the domain nave system root database.

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The program for INET'92 was divided into several keynote lectures and then four parallel tracks,

- regional
- policy
- applications, and
- technology.

A workshop for developing countries was also held on the opening day along with several other tutorials. Finally, during the conference a number of regional ad hoc meetings were held. In this summary we focus on Asia related papers and particularly on networking issues in Japan. A complete list of titles and authors is attached to this report, as well as the electronic addresses of all the authors and session chairs. For both of these I wish to express my gratitude to Professor Ishida. Also thanks to S. Goldstein of NSF, who explained many arcane technical details to me. (Because email addresses are attached, I will omit my usual practice of including detailed addresses of noted speakers within the text.) Of more than 80 papers presented at INET'92, 61 were included in the proceedings. Ishida explained that almost all the papers were submitted via electronic mail (in LaTex form), an impressive feat. In fact, the author list does not really give a good sense of how widespread the Internet has become. One afternoon, an informal meeting of those interested in the Asia-Pacific area produced attendees from Australia, China, Hong Kong, India, Japan, Korea, Malaysia, New Zealand, Papua New Guinea, Sri Lanka, Thailand, Taiwan, and Viet Nam.

The closing session involved a panel on the future of the Internet. One problem is simply success. The Internet has grown so rapidly, that management (in every sense) can no longer be dealt with lightly. (This is a problem that many organizations wish they had.) Related to this was security, which is a growing concern. This includes willful damage and also accidents (witness the chaos that recent telephone outages caused in the United States). The panelists also painted an astonishing picture of possible services available on a future Internet, and I admit to being caught up with this. But we were all brought back to Earth by several audience participants who criticized the speakers as being too United States (and European Community) centered, and reminded them that many countries exist where even a 2400-baud telephone line is a luxury not widely available. This led to another discussion concerning problems with access to the Internet by countries that do not have best relations with the United States. I doubt that anyone at this meeting was qualified to comment on legal issues, but the point was made by many INET'92 attendees that the Internet was a truly international organization, not a U.S. one. (Just like the UN.)

The keynote speech was delivered by Toshitada Doi, from Sony, on the topic of multimedia networking. In point of fact it is not easy to move non-ascii material on the Internet. Mail files are defined as ascii. If the source and destination machine run one of a few standard encoding/decoding programs, such as uuencode/uudecode, then non-ascii files can be mailed. Otherwise ftp (file transfer protocol) is the only accepted alternative. I am told that a multimedia extension of the mailing protocol (MIMI: Multipurpose Internet Mail Extensions) is "nearly" ready and will address the issue of sending multi-font text, images, and audio.

However, Doi's speech was not about the bits and bytes of networking; instead, it focused on the human need to have face to face communication and the implications for electronic networks in terms of vastly increased capacity requirements for movement, speech, and related information. Doi stated that the most important issue of the decade was the requirement for dealing with emotional information. He gave a few examples of work in this area, such as Sony's 3-D face model (involving agent interactivity), more theoretical studies of "people", and claimed that early work at Xerox PARC has hardly been surpassed even today. Finally, he mentioned, only half in jest, that understanding human communication was one reason that Sony purchased Columbia pictures. He also commented about some of the negative aspects

of the networked society, as for example staring at a crt screen all day. This paper was particularly interesting to me, as I had just learned that both MITI (Ministry of International Trade and Industry) and Mombusho are funding research on information processing of emotion and sensitivity (see a forthcoming report "kansei.92".)

There were seven papers related to Asia and the Pacific region. Five were of general interest (there were also several other papers of Japanese authorship on more specific technical topics). Among the general reviews, Ishida presented a summary of the academic networking situation in Japan as well as an historical chronology. Jun Murai, from Keio University, discussed WIDE, a research project to interconnect several networks in a transparent way. WIDE is the most active networking activity in Japan at this time, and Murai is considered to be one of the most effective (and animated) proponents of networking in Japan. Surveys of networking activities in Korea [Choi, Seoul Nat. Univ.], and in the (PR) People's Republic of China (Hu, Tsinghua Univ.) were also presented, as well as a more general overview of the situation in other countries in the region (Hine, Victoria Univ., New Zealand).

We summarize the key points here.

JAPAN

Internet is lagging in Japan compared to Western countries. There are various reasons, including the emphasis on centralized computing (and a centralized social view including a belief that Japan as a small country permits easier face-to-face contact) emphasis by vendors on proprietary network protocols, slow acceptance of TCP/IP as a standard and a determined push by the Japanese government on OSI, problems with input of Japanese language, and general problems related to the cost and availability of telephone lines and related regulations. Also, a heavy emphasis on ISDN development meant that funding lagged for other projects that tended to rely on volunteers.

In any case, the current situation is that four main networks link Japan and the United States. (All net traffic to Europe transits the United States.) These are as follows:

- Bitnet: Through the Science University of Tokyo on a 56 kbps line to Princeton. (SU-Tokyo also links to Korea and Taiwan.)
- NINET: A mainframe-access oriented network through National Center for Science Information Systems (NACSIS) (run by Mombusho) on a 136 kbps line to NASA.
- JUNET/WIDE: A link to U-Tokyo and then via 128 kbps link to Hawaii.

A link to Keio U and then via 192 kbps link to Hawaii. This is the most important net link for academic users. From Hawaii there are links to Korea and New Zealand, as well as to other Internet sites

- HEPNET-J: A specialized net through Japanese High Energy Physics Lab (KEK) and then via a 56 kbps line to Berkeley's HEPNET.

(There are also other specialized nets, of which HEPNET-J is typical.)

The NI work began in 1973, but it was not focused on email and had no provision for Japanese text. It wasn't until 1984 when Jun Murai set up an email/enews network (JUNET: Japanese University/Unix Net), using 9600 baud telephone lines and uucp to link Unix systems at three universities. This was a tremendous success. JUNET was operated completely on a volunteer basis; it was an unofficial network with no recognition from the Japanese government. Bitnet came in 1985, and in 1986 JUNET was connected to CSNET in the United States. In 1987 Murai initiated WIDE, which was a leased line extension of JUNET, with 64-192 kbps lines and TCP/IP, and a 64 kbps line through Hawaii in 1989.

In more detail, concerning the seven major academic Internet currently in Japan.

- WIDE, with 58 domains and 6 Network Operation Centers.
- BITNETJP, with 118 nodes in 82 institutions (domains).
- SINET, with nine domains associated with the NACSIS. This is the center of the NINET and also of a library network linking major university libraries in Japan via N1 protocol. In 1991 NACSIS began supporting TCP/IP, thus it is in a position to compete and complement WIDE internationally.
- JAIN, with 44 domains is an experimental academic Internet linking universities with 9.6 kbps or 48 kbps X.25 lines provided by NACSIS. It will probably be absorbed by other networks when experiments supported by the Ministry of Education are completed. JAIN might pursue gigabit networking but at the present there is no definite plan.
- TISN, with 17 domains is an Internet linking 2 universities and 15 labs at 9.6-64 kbps. It

has a 128 kbps link to the U.S. Internet through the University of Hawaii.

- HEPNET-J is a network centered around the Tsukuba High Energy Physics Lab (KEK) with a 128 kbps line to U.S. HEPNET through Lawrence Berkeley Lab.

- TRAIN & UTnet. TRAIN is the first major regional internetwork developed around the University of Tokyo Computer Center, with several 64 kpbs links and three multiline routers. UTnet is a member of TRAIN constructed under a three-year project (1990-1992) by a Mombusho grant. It has three FDDI rings and a 400 Mbps multimedia ring connecting major buildings in the main campus. Within buildings, twisted pair Etnernet connects various PCs, workstations, and mainframes. There are also three-leased lines to two other U-Tokyo campuses, two at 769 kbps, and one at 1.5 Mbps. Presently, the latter is of the highest speed in Japanese networking.

Ishida described four notable applications of Internets in Japan.

1. Access to several versions of the massively parallel computer, AR 1000 from Fujitsu.
2. GenomeNet for human gene data exchange.
3. Distribution of physics preprints.
4. Inet Club, a consortium of nonuniversity organizations that want access to WIDE.

Ishida also pointed out that the key ingredients in further internetworking in Japan are

1. Additional financial support
2. More coordination between existing Internets in Japan
3. Increase in number of freely accessible systems
4. Faster links
5. More students and researchers interested in networking
6. Industrial support for TCP/IP and less emphasis on ISDN and OSI
7. Japanese subsidies for links to other Asian countries.

Jun Murai's talk on WIDE mentioned some special research activities that include dealing with the Japanese language and also the handling of ISDN. The latter is important because availability of ISDN provided by NTT is high in Japan. There was an ISDN telephone on the street around the corner from the conference hotel in Kobe. Another research activity is aimed at the use of satellite communications, in particular to use currently unused communication satellite bandwidth for multicast communications, allowing file transfers to go via satellite. A transponder will be available this July for experimentation. (Satellite communication is much less stable than terrestrial communication.)

Murai noted that very soon commercial access to the Internet will be available here through WIDE. He made an excellent point about growth of networks in Japan, showing that, now, the number of domain names for commercial organizations "co.jp" is more than double that of universities "ac.jp". On the other hand, the number of Internet Protocol connected domains of commercial organizations was less than half of that of universities. WIDE is the only IP network connecting commercial organizations, and then only to its research partners. Murai sees the need to have commercial access to the Internet and has been working to transfer its technology to various companies and also helping the planning of new networks.

The issue of coordination between networks is finally being taken seriously with the establishment of the Japanese Network Information Center, (JNIC) (Email: JNIC@NIC.AD.JP). There was also a discussion about very-high performance backbone networks, such as a gigabit backbone. For this, however, financial support is needed. Knowledgeable participants were all saying "something might happen."

SOUTHEAST ASIA

This is based on a paper by Hine (New Zealand) that describes work he has been doing with UNESCO. Hine surveyed networking in a dozen countries. Here I state a few summary facts.

Pacific Islands (such as Tonga). Plans are to have X.25 in the near future. Dial up and leased lines are available, but seldom they are above 2400 bps. The University of the Pacific (Fiji) has a history of satellite communication for education, and can be reached by dial-up uucp to New Zealand.

Australia has a research network that connects over 200 organizations. A 256 kbps links to the United States.

New Zealand has an internetwork and some universities' research networks. The Country is reorganizing its government-funded research, which has resulted in confusion and slowdown of the networking.

Southeast Asia A typical situation is to have a single site that has established an international link for email, commonly X.25 to uunet in the United States or dial-up to the University of Melbourne, Australia. Hine commented that some of the countries have weak internal telephone infrastructure with old and

unreliable equipment and low-speed lines.

Indonesia has an educational net (UNInet) that serves six universities and plans in place to connect all 45 state universities by the year 2000. UNInet uses uucp over X.25 and dial-up with an effective rate of 800 bps.

Malaysia has a project to construct a research and education net, JARING, linking hubs in 11 centers by 64 kbps leased lines. There is an X.25 link to UUNET in the United States, but it is expensive. There is also a 4.8 kpbs Bitnet link to Singapore.

Papua New Guinea has a 1200 bps uucp link to Melbourne.

Laos has no national or metropolitan networks. The telephone system is saturated, and no improvements are expected until the end of 1993.

Philippines have a few uucc connections. Educational and research networks are limited to LANs on two university campuses and a network bulletin board system using Fidonet.

Thailand has a national research network, NECTEC that connects several universities as an X.25 network. The international gateway is the Asian Institute of Technology, again a dial-up uucp to Melbourne. Only email is provided. I have contacted AIT in this way, but large email messages are not accepted. Plans are in place to connect to Internet and Bitnet by the end of 1992.

CHINA

Hine reported on China, but as I mentioned earlier, Daoyuan Hu (Institute of Integrated Network Technology) Tsinghua University, Beijing, gave a much more detailed description of networking activities, and I outline the key points he made.

National Computing and Networking Facility of China (NCFC) is a demonstration network that covers about 5 km^2 in Beijing. Within this area are several universities (Tshingua, Beijing Univ.), and major institutes of the Academy of Sciences of China (CAS). Hu claims that there are tens of thousands of professors and engineers in this district. NCFC is a two-level system. A 10 Mbps backbone connecting three campus networks and the network control center (this could go to 100 Mbps). Communication protocols are aiming at 150/051, but TCP/IP is the first phase protocol. The backbone design is completed as is cabling. The second level is composed of campus networks at the two universities and CAS. Hu described the TU net in detail, but I omit this here except to note that it seems to be well planned. It already has hundreds of computers connected and other services are in place or soon will be.

A key function of the networks is to allow electronic mail, and Hu explained that TU is setting up a message handling system (MHS) that includes mail, telegraph, teletext, fax, videotex, voice, images, etc. The MHS has been developed under contract by the University of British Columbia and based on message transfer agents, collaboration with the GMD, and Chinese text.

The China Academic Network (CANET) is connected to the Internet by a store and forward system at the University of Karlsruhe, Germany using an X.25 link. There is no TCP/IP connectivity yet. There is dial-up access to CANET from inside China. I can report that I frequently communicate with Chinese scientists via CANET.

KOREA

Korea is in fairly good shape relative to other countries in the region. Over 50 organizations are now connected to three major academic and research networks, Hana/-SDN (an outgrowth of the earliest network that connected Seoul National University and Korea Institute of Electronics Technology in 1982) KREONet (government sponsored network connecting research institutes and some universities) and KREN (also government sponsored, connecting universities). Hana/SDN now has 15 members and uses 56 kbps leased lines between sites, and also a 56 kbps line to the United States Internet. KREONet is centered at System Engineering Research Institute (SERI) in Daeduk Science Town. It provides access to SERI's Cray 2 and other network services. User organizations are also connected by 56 kbps lines, and there is a 56 kbps line to the Internet at the San Diego Supercomputer Center. KREN connects 14 educational institutions through Seoul National University. It has a 9600 bps line to Bitnet in Japan.

So a large amount of networking exists, and the busiest traffic is to the U.S. networks, and intraregional traffic is minor. There are plans for greatly increasing the quality of services to be offered, based on estimates of growth in the number of users (100,000 by 1995) and enhanced service offerings. Plans are evolutionary. Step one is to have the three networks share a high speed (T1) link to the United States and from subnets to the hub at 512 kbps. Step two calls for increasing the international link to T3, and connecting the subnets through frame relay (FR) backbone. It is estimated that this can be done by 1995 or 1996. Step three calls for replacing the FR backbone with an ATM (asynchronous transfer mode) backbone. Access from subnets will vary between 155 and 622 Mbps, and the international link will go to T5. T1 links to

Japan, China, Europe may also be put in at this time. An ATM network will not begin in Korea until 1997, and it is linked to the telecommunications carrier's schedule. Funding for some of the needed R&D seemed to be vague.

REAL WORLD COMPUTING (RWC) NETWORK

MITI took the occasion of INET'92 to have a session describing their RWC program (see my report, "rwc6-92", 10 June 1992). The session was sparsely attended because it really did not fit well with this conference, but there were a few interesting points nonetheless. H. Asoh (asoh@etl.go.jp) gave a general overview of RWC, most of which has been published. He pointed out that the budget will be 50-100Billion Yen (US$370-740M) over ten years from MITI, and that this is one fifth to one tenth of the U.S. high-performance computing and communications initiative. Asoh also commented that RWC is not a plan to build a Japanese CM-5, and that the program represents a new role for MITI. Again, I noted the efficient Japanese process of moving scientists from labs to MITI and back; Asoh spent the past year at MITI helping to organize RWC, now he is back at ETL (Electrotechnical Laboratory) in a more technical role, his position at MITI is now occupied by another ETL scientist.

M. Tsukamoto (tukamoto@etl.go.jp) described MITI's plans for a network to allow RWC collaborators to work together and with the facilities being set up at the Central Research Laboratory (CRL) in Tsukuba, in particular to make use of a planned massively parallel computer. Other functions include a network window system, remote access to research information at the CRL such as remote database (DB) access and network file sharing. Of course there are also plans for electronic mail, electronic notice board, electronic meetings. Network protocol will be TCP/IP and there are no plans to use OSI. The plan is to establish a 512 kbps link between CRL and a Tokyo Network Operations Center, plus two other links from TNOC, one at 192 kbps to various Japanese academic centers, and a 512 kbps link to a collaborator site in Europe. When this occurs, it will be the first direct research oriented network from Japan to Europe. Of course, it is possible to communicate between these two locations now, but this involves passing through a U.S. network. The new net, called RWC Network, will still physically go to the United States, but will not depend on U.S. networks there to transit to Europe. The RWC also anticipates having distributed labs; these are likely to be at various Japanese company facilities. Tsukamoto explained that it is possible that they will connect to the TNOC through leased lines. RWCNet will be designed by July 1992, international testing will be done by March 1993, and the net should be in operation by April 1993. It is expected that reviews of the system will be done yearly, and major review will be conducted in April 1997.

Since the MITI slides only showed Japan and Europe, I asked about other potential RWC collaborators, such as in Australia, other parts of Asia, Canada, United States, etc., (the United States is not yet directly involved and may not be). Apparently this is sensitive and there were no direct answers. Eventually I was told that the budget was not unlimited, but that "free riders" on the net would be welcomed if they were academic researchers.

You can send comments about RWCNet to the address: RWC-NET @ETL.GO.JP.

JOINT SYMPOSIUM ON PARALLEL PROCESSING, 15-17 JUNE 1992

This article summarizes the Joint Symposium on Parallel Processing held 15-17 June 1992 in Yokohama, Japan.

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I have added some of my own comments. Where necessary, I have initialed comments with DKK and UW.

Many of the projects mentioned here have also been discussed in detail in earlier reports of mine, and these are noted when appropriate. Also see the survey report, ["jhpc-pp.92", June 28 1992] on my E-mail: KAHANER@CS.TITECH.AC.JP.

The Joint Symposium on Parallel Processing (JSPP) is one of the two important annual conferences on parallel computing in Japan—the other being the Summer Workshop on Parallel Processing. Most Japanese researchers in the field of parallel computing attend at least one of these conferences. This reports on the fourth JSPP, which had a record attendence of about 300 (mostly young) researchers and about 60 papers presented in three parallel sessions. Papers submitted to JSPP are not refereed in the usual sense and are often presented at international conferences in English. Papers may be submitted in either English or Japanese, but only a few (3 out of about 50 for JSPP) of the papers are written in English in the Proceedings; the working language of both meetings is Japanese. [A full list of the titles and authors of the papers is given at the end of this report. The Proceedings (469 pp.) has abstracts in English.]

The state of parallel computing research in Japan is probably about three of four years behind the United States, with a few interesting exceptions. From the excitement and urgency I felt at this conference, Japan clearly views parallel computing as a strategic technology. In particular, the three big computers companies that currently build supercomputers—Hitachi, NEC, and Fujitsu—see that parallel computing is the future of high-speed computing. However, none of the companies has significant commercial parallel computers and, in fact, do not necessarily even have significant research projects. [This is not the case for either Fujitsu or NEC DKK/UW]. Unlike the United States, where parallel computing is primarily the domain of relatively small, innovative startup firms like Thinking Machines, nCube, KSR, Tera, and Wavetracer, with a few more mainline companies like MasPar (DEC) and Intel, Japan has no computer companies specializing in this rather risky, untried territory. Japanese companies tend to wait for trails to be blazed, and then follow—in general, they are quite conservative.

[DKK and UW comment.] Fujitsu's AP1000 is about as close to a commercial general-purpose parallel computer as one can get. Cenju-II may be the next parallel system entering the Japanese market (after AP1000). Up to now, much of the parallel computing R&D has been done in small, isolated groups. But the growing amount of cross-evaluation of existing machines is an

indication that "real" applications are not far off. The panel on Conditions for Practical Use of Parallel Computers, Commercialization: Analysis of deficits and countermeasures made it clear that there are two lines of thought. Researchers need cheap tools, whereas companies are looking for revenues. Hitachi put it most clearly. In spite the high performance, good value/performance ratio, scalability of massively parallel processors, the market for general applications computers vs vector computers vs parallel computers is estimated to be 60:10:1 at the moment. With the general tendency to downsize, it is difficult to decide when to jump in. On the academic side, "grand challenges" seem to be needed to boost the R&D efforts in mpp. Whether the required extra budgets will be provided by the Ministry of Education seems doubtful. Another point mentioned by the panel members was the need to introduce parallel computing at an early stage into the current curriculum of information engineering.]

Research papers in this conference came from three sources: industry, academia, and government labs. Of the three, only industry has the resources to put forth a large research effort, and for the most part, they have been rather timid. Academia in Japan is extremely underfunded due to a lack of interest in corporate/academic relationships, and to a lack of support from the Japanese government. University research falls under the jurisdiction of the Ministry of Education (Monbusho). Monbusho's total budget is very large, but this is mostly for the operation of universities; its research budget and political weight are much more modest when compared to the Ministry of International Trade and Industry (MITI), which supports industrial research efforts. For example, the recently completed Institute for New Generation Computer Technology (ICOT) project was supported by MITI using a combination of government and industrial resources [see "icot.692", 4 June 1992]. [Most observers feel that MITI's leverage on Japanese industry is much less than in the past. DKK]

I am most familiar with the efforts in the government labs, because I have been working in what is perhaps the only significant government research project in parallel computing in Japan: the dataflow work at the Electrotechnical Laboratory (ETL). By American standards, our group, the Computer Architecture Section, is rather poorly funded—the budget is probably about one-third of the budget of my research group at MIT. However, in spite of (or perhaps because of) this limitation in money and people, our group at ETL has managed to produce what is probably the most interesting work in parallel computing in Japan.

Below is a rough histogram of the sources of papers at JSPP. Although counting papers is a rather inaccurate way to measure the quality of research, perhaps this simple exercise can give a general idea of where parallel computing research is begin done in Japan. In the case where one paper was cowritten by multiple institutions, I counted each institution once. Multiple authors from the same institution were only counted once. Everyone else had only one paper.

Tokyo University	9
ETL	6
NEC	6
Kyushu University	5
ICOT	4
NTT	4
Tsukuba University	4
Waseda University	4
Fujitsu	3
Kyoto University	3
Osaka University	3
Hitachi	2
Matsushita	2
Mitsubishi	2

The papers were divided into subjects, and each session had three papers, with three parallel sessions going at the same time. The papers were divided as follows:

Architectures	24
Applications	12
Software	9
Basic	9

There were also invited speakers and panel discussions.

In general, the architecture papers tended to be presented by industry, and the rest of the papers were fairly evenly divided.

The conference was held at the newly built Yokohama Pacifico Hotel, on Yokohama Bay. As is the case with many things in Japan, the hotel was brand new, having just opened three months ago in March. Planning for the conference in an unbuilt hotel must have been a bit difficult. The area around the hotel looked rather un-Japanese, in that there was a lot of wide open, undeveloped land. In all, it see incredibly spacious in comparison to most of Tokyo. The land in the area was reclaimed from the ocean, and a great deal of development was in progress. Across from the Pacifico is a half-built Mitsubishi building, which will be the tallest building in Japan when it is completed, and next to the Pacifico is the new National Athletic Center. [This was also the location of Supercomputing Japan'-92, see "sc-j-92" 27 April 1992.] All in all, the newness, the technology, and rate of development around the hotel impressed me.

Although at present, the state of Japanese research in parallel computing is slightly behind the United States, I was struck by the feeling

that if Japan seriously considers parallel computing a strategic technology, it will put forth the efforts to become the world leaders in this field, as it has in so many other fields.

The conference began with an invited talk by Kunio Kuwabara, of the Japan National Aerospace Laboratory, showing the advantages of the visualization of numerical calculations. Most of the talk was focused on demostrations about fluid dynamics. First, there were videos of flows around circles, triangles, and squares; then around buildings and in offices; and over wings and around cars; and then over the main Japanese island of Honshu and the southern island of Kyushu; and also of a ski jumper. The ski jumper must have had a special significance because of the great success of the Japanese ski jumpers at the Winter Olympics in Albertville. All in all, I got the impression that the gist of the talk was—"Gee, look at these neat demonstration," "Visualization is important," and "We need a ton of computing power to do these simulations, and now we have it, and we'll get more soon." Unfortunately, I did not get much technical information, although perhaps it was because my technical Japanese was not strong enough to follow much. However, all of the slides were done in English (as was the case with many of the presentations), and I don't think that the talk was meant to be very technical.

The second invited talk was by Hiroaki Kitano, who is associated with NEC and Carnegie Mellon University (CMU). Evidently, there is a strong possibility that he will become a professor at CMU, but he has had some visa problems. He has been a visiting researcher at CMU for the past two years, and he is a codirector of the International Consortium for Massively Parallel Computing Technologies (IMPACT). Most of his talk centered around the possible applications for massively parallel computers. Although his talk was entitled, "Massively Parallel Artificial Intelligence: Today and Tomorrow," most of the applications he discussed were standard supercomputer applications, similar to and including the "grand challenge" applications. The most striking proposal to me (and evidently to some of the other Japanese researchers) was the proposal to use real-time "sensor-fusion" computing to provide a competitive advantage in the Japanese "America's Cup" entry. Like the ski jumping example, the exploits of the "Nippon" entry to the America's Cup this year was a source of great pride and interest to many Japanese. Dr. Kitano suggested putting sensors all around the boat to measure various data and then processing them by using massively parallel computers. It was all rather vague, but exciting. Once again, I got the feeling that people might have been a little bit disappointed by the lack of technical content, but as an invited talk, its subject matter was probably too broad to provide much time for meatier, technical issues.

Most papers on architecture described improvements in existing projects. H. Terada (Osaka University) announced the one-chip dataflow processor RAPID, developed with Mitsubishi Electric, which includes floating-point processing, contains addressable memory, and has peak performance of 50 MFLOPs.

S. Ono and his group at NTT Transmission Systems Lab described their 12.8 GFLOPs parallel signal-processing system NOVI-II HiPIPE, with a 128-PE mesh built on a 100-MFLOP pipeline processor. Applications are to be super-high-definition image processing.

M. Ishikawa, of Tokyo University, known for research in optoelectronics, described a system made of 64×64 sensory elements with attached 4×4 bit processing capability, "SPE 4k." He gave examples of image processing, including edge detection and detection of moving objects.

Two interesting talks were given by the AP1000 group at Fujitsu. In my opinion, the AP1000 is probably the most interesting [pre-]commercial parallel computing project in Japan. [See "aplooows.91" 2 Jan 1991, "austrl.791" 6 Sept 1991, and "jhpc-pp.92" 28 June 1992.]

The first talk was about all-to-all personalized communication. In the United States, most of the interesting work in all-to-all personalized communication has been done by Lennart Johnsson and C.T. Ho, of Yale and Thinking Machines. All-to-all personalized communications is used for situations where each processor must send different data to every other processor. For instance, consider a situation where each processor of a parallel computer contains one column of a matrix. Inverting the matrix efficiently would require all-to-all personalized communications.

Dr. Horie presented an algorithm for processors connected in a ring and then a 2-D toroidal mesh, and then generalized his algorithms to a k-ary n-cube. In each case, he assumed circuit-switched or wormhole routing and one-port communications. The AP1000 uses a circuit-switched 2-D toroidal mesh, and he implemented the version on the AP1000. For a 256-processor AP1000, the algorithm took about 80 μs/byte. For a 64-processor AP1000, about 10 μs/byte.

The second talk on the AP1000 was identical to the paper that Horie et al. presented at this year's (ISCA) in Australia (Proceedings, pp. 288-297). Basically, it concerned sending messages in user-mode directly from

the cache into a circular buffer—something they call "line sending and buffer receiving." Interested readers are referred to the English version in ISCA.

Two students of Akinori Yonezawa of Tokyo University spoke about their efforts to implement Yonezawa's object-oriented language ABCL on the Fujitsu AP1000 and the ETL EM-4. Professor Yonezawa was a Ph.D. student of Professor Carl Hewitt at MIT, and he is interested in object-oriented programming. Both of the talks were quite interesting, but neither the graduate student working on the EM-4 nor Professor Yonezawa seemed to give a straight answer to the obvious question: "Which is better, the AP1000 or the EM-4." Shaw comments: "My guess is that for communications and synchronization, the EM-4 is probably faster than the AP1000 within a factor of two, and for sequential computation, the AP1000 is faster within a factor of two." The paper about the implementation of ABCL on EM-4 appears in the Proceedings of this year's International Conference on Supercomputing that was held in Washington, D.C. in July 1992.

The next day, I attended a talk by Tsutomu Maruyama, of NEC, about a parallel graph-partitioning algorithm. NEC's parallel machine is called the Cenju, and it appears to be some sort of 68020-based distributed memory machine—I think that they have implemented a 64-processor version. The successor to the Cenju, the Cenju-II is based on the MIPS R3000, which NEC manufactures, but I believe that the architecture is otherwise similar. The Cenju is primarily used by NEC in-house for gate-level circuit simulation. Evidently, it has performance that is superior to their SX-3 supercomputer for this application. [See "spice" 2 July 1990 and survey report "jhpc-pp-.92" 28 June 1992, mentioned earlier.]

NEC would like to expand the application base of the Cenju, and the talk by Dr. Maruyama was related to their work in running a circuit layout program on their machine. The graph partitioning algorithm in the paper improves the speed of the min-cut algorithm using genetic algorithms to improve decisions during cutting. Unfortunately, I was not able to get much of a feeling for the details because of my limited technical Japanese.

I had heard all three of the talks in the following Architecture section, because they were all by members of my research group. The first talk was by Shuichi Sakai, who is the chief architect in the EM-4 group of which I am a member. Dr. Sakai nominally presented a paper on the effects of grain size and network load. His contention is that small grain sizes are better until the network is saturated. From that point, a larger grain size is more efficient. To illustrate his point, he showed a program that summed a series of numbers recursively, splitting the range. Each invocation first checks the network load and recursively splits if the load is low and performs the sum locally if the load is high. Unfortunately I don't think that he had any concrete ideas of how to implement this automatically in a compiler, but dynamically changing the grain size of computation was a very interesting idea.

I say "nominally presented a paper" on this subject, because he spent most of his time discussing the advantages of fine-grained computers and the amount of hardware support necessary to implement fine-grained computers, as well as the various factors that go into designing parallel computers. All in all, Dr. Sakai presented a strong statement of purpose, position, and ideals; this was unusual for a Japanese researcher.

Dr. Sakai will be the head of research for the parallel processing section of the new Real World Computing (RWC) initiative, which in some ways is the successor to the ICOT project [see "rwc6-92" 10 June 1992]. RWC will be incredibly well-funded, and Dr. Sakai will have a chance to build his followup to the EM-4, the EMS. Presumably, he will incorporate some of his ideas about dynamically changing grain size into EMS.

The next talk was by Sholin Kyo, of NEC, who presented work he did while he was visiting our group at ETL last year. Basically, the work was about the performance of the switch operator, which is in some ways analogous to a branch in von Neumann computers. He compared the performance of the NEC imPP dataflow chip against the EM-4 and Sigma-1 in a measure he called SwIPS (Switch Instructions per Second). One problem with the talk was the assumption about the pure dataflow programming model which uses switch. I think it's unlikely that any more real machines will be built using the pure dataflow model and that the importance of switch will dwindle.

Another researcher from my group, Satoshi Sekiguchi, presented a paper giving a performance evaluation model to find optimal grain size given characteristics of the programming model. He stressed the importance of synchronization, forking, and context switching.

In a parallel architecture section, Hiroaki Hirata, of Matsushita, presented a paper that he also gave at this year's ISCA (pp 87-96) entitled "An Elementary Processor Architecture with Simultaneous Instruction Issuing." There were several more papers about superscalar and very

long instruction word (VLIW) machines.

I was not able to follow very much about the panel discussion, except that many people and companies in Japan realize the importance of parallel computing in terms of price and performance and in terms of parallel computers eventually replacing traditional vector supercomputers sometime in the next 10 to 15 years.

However, one presentation during the panel discussion definitely stood out. Makoto Yamada, of Nihon Thinking Machines, started with a big, full-color picture of Danny Hillis and continued as a heavy sales pitch. This was in stark contrast to everything else in the conference, which was quite research-oriented. It was a bit disconcerting to listen to a talk about a real machine being sold today to real customers, solving real problems. In one sense, it was disappointing, but it was also intimidating to realize that much of the research being described in the room was running on a real product, being sold by an American company. (After living in Japan for a while, you begin to subconsciously believe that everything Japan builds is superior and high-tech, and everything America builds is junky and low-tech, and that America is years behind in everything technological. This is not the case, of course, but most of the Japanese media would lead you to believe this.)

Specifically, I remember one question about the business applications of massively parallel computers. After a relatively "what if" answer by one panelist, Dr. Yamada stated that Thinking Machines had at least two business customers in Dow Jones and American Express and that there were several other business-application-oriented customers interested in the CM-5. Perhaps I was reading too much into the reaction of the audience, but they seemed a little bit hostile to the American company—or perhaps they seemed edgy about the distinctly nontechnical, sales quality of the Thinking Machines presentation.

My talk was about data-parallel programming on the EM-4. Basically, I gave implementations for element-wise operations, scan, broadcast, reduce, barrier synchronization, and vector permutation using the general communications network. Each of the communications sections of scan broadcast, reduce, and barrier executed in about the 10-μs range on 64 processors. Element-wise operations and permutation were bound by the sequential performance of EM-4, which I timed to be comparable to a Sun 4/330—a sequential processor designed and implemented at about the same time as the EM-4. Finally, I ran a parallel radix sort program that showed about a 3X overhead for parallelization but which was faster than an identical algorithm running on an identically sized CM-200 and also faster than the TMC system sort provided as part of the CM-200 software environment. I will be giving an extended version of my paper at Frontiers of Massively Parallel Computing this October in McLean, Virginia.

Although there were several papers in English, I believe that I gave the only presentation in English at JSPP this year. I think that most of the audience probably had some difficulties understanding my talk, but they were probably used to reading English slides, so they probably understood most of it. I got several very good questions after the talk, all in English, and there were many people who were interested in the work who talked with me afterwards.

In the final session, I attended the architecture track, which was about dataflow computing. The first talk by Yuetsu Kodama of ETL was about the design of the EMC-Y processor chip used in the EM-X, which is one of the successors to the EM-4. EM-X has several features that EM-4 does not. By far the most important feature is floating-point support—at this point, it is likely that EM-X will have only a 32-bit floating point. There is a small possibility that it will have a 64-bit floating point. Also, the EM-X will be character addressed, unlike the EM-4 which was word-addressed. For sequential computation, floating point and string or character manipulation are the two weak points of EM-4.

Other than that, Mr. Kodama and Mr. Koumura, of Sanyo Corporation, the industrial partner for the EM-4 project, did some simulations to determine the optimal network input packet buffer and output sizes. From their simulations, they determined that EM-4 was just right—16 input packets and no output buffer at all. There will also be some improvements in the routing, memory addressing modes, token address manipulation instructions, and the token matching protocol. However, in general, the EM-X will be quite similar to the EM-4. One problem that I had with the simulations was that only two programs were run: recursive Fibonacci and a checkers program. However, that is one of the big weaknesses in the current EM-4 project—the lack of applications software.

The next talk was about the EDDEN (enhanced data driven engine) developed by Sanyo. The company markets a 64-processor element (PE) version under the name "Cyberflow," as a graphics workstation. It executes the pure dataflow model, and it only has 32 token colors, which severely limits its programmability. On a 64-processor system, the EDDEN showed moderately impressive results on some Livermore loop kernels.

The last talk I attended at JSPP was by my boss at ETL, Dr. Toshio Shimada, who gave a talk about the performance of the Sigma-1 dataflow computer, which he helped to design and build. It was unfortunate that there had been no real performance evaluation of the Sigma-1 before this point. The Sigma-1 has very good floating-point performance (10 MFLOPs/processor) and is the largest dataflow machine in existence (128 processors). However, there was very little software written for the Sigma-1 up to this point, and the programs run for this paper were relatively small. The new HP-750 workstation obtained about the same performance as 50 or 60 processors of Sigma-1, given a large problem size for smaller problem sizes, the HP was faster. Of course, a large part of the problem is that the Sigma-1 is dated technology—about four or five years old. But another part of the problem is that the Sigma-1 uses the pure dataflow model (very similar to the MIT TTDA architecture), which I think Dr. Shimada would admit is probably not as efficient as the hybrid dataflow/von Neumann model similar to the EM-4. In general, I think the fact that a performance evaluation of the Sigma-1 was done four years after the Sigma-1 began running is indicative of the state of parallel software for dataflow in Japan. I don't know if I would extend that statement to parallel software in general in Japan.

All in all, JSPP was a surprisingly interesting conference. Many of the papers were of very high quality, as shown by the fact that they were accepted in their English versions for other prestigious international conferences. There were probably less than 10 foreign researchers who attended the conference, which is probably more than in recent years. It is unfortunate that so few attended. Although many of the more interesting papers were presented in English language conferences, it is also likely that some of the interesting work will not be presented in English for some time to come. It is most likely that the interesting research in parallel computing in the near future will be done in the United States or in Japan—and although the current state of Japanese research is probably a few years behind the United States, every Japanese researcher can read English papers published in international conferences, whereas probably only a handful of American researchers (among which I do not count myself) can read Japanese papers published in Japanese conferences.

Proceedings of the Joint
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Processing 1992
15-17 June 1992
Yokohama, Japan

AUTOMATIC DIFFERENTIATION COMMENTS FROM DR. ANDREAS GRIEWANK

This article reports on comments from Andreas Griewank re automatic differentiation. Dr. Andreas Griewank, Argonne National Lab, [griewank@antares.mcs.anl.gov] sent the following comments after reading my report on autodifferentiation in Japan [see "autodif.92", 30 May 1992].

by David K. Kahaner

Your basic characterization of automatic differentiation is correct, even though I would not position it as somewhere between differencing and symbolic differentiation. It really has nothing to do with the former but could rather be considered a variation of the latter. In fact, the Maple group under Michael Monogan has just released a library for computing gradients, Jacobians and Hessians by Automatic Differentiation (AD). Here AD means in contrast to fully symbolic formula manipulation that the chain rule is applied to numbers rather than algebraic expressions. In other words the partial derivatives of arithmetic operations and intrinsic functions are evaluated at the current argument and then multiplied by some variation on the chainrule.

A key point that was probably not known to R. Moore and unfortunately never stressed enough by L. Rall, is that the chain rule can be applied in various ways. One of those variants is the so-called reverse, top-down, or backward mode, which yields gradients at no more than five times the number of operations needed for the evaluation of the underlying scalar function. This complexity bound is completely independent of the number n of independent variables. In contrast, the cost of estimating a gradient by differencing is $(n+1)$ times that of evaluating the function. The complexity of fully symbolic approaches grows typically exponentially in n.

Your statement that the computational cost (of AD) is greater than that of numerical differentiation (i.,e. differencing) is therefore inaccurate. It is sometimes not even true for the so-called forward mode of AD, whose complexity is proportional to that of differencing. Depending on the particular problem and the computing platform, the proportionality factor for the actual run-time may be smaller or larger than one, and lot depends, of course, on the way in which AD is implemented. By generating compilable code that incorporates portions of the reverse mode wherever advantageous, we hope to eventually consistently beat differencing in terms of run-time. Hand coded versions of the reverse mode are routinely used in weather forecasting and other control applications, where the reverse mode is simply a discrete analog of the well-known adjoint or costate equations. In short, the topic is not as cut and dry as it may seem, and currently there is a considerable amount of research done in the area. In the context of our C/C++ implementation ADOL-C, we are working in particular on the reduction of the potentially very large storage requirement of the reverse mode.

For a recent survey, you could check my article "The chain rule revisited in scientific computing", which appeared in two parts in the May/July issues of "SIAM News" last year. The proceedings of a workshop called "Automatic Differentiation of Algorithms, Theory, Implementation and Application" edited by myself and George Corliss were published last December by SIAM. The volume includes survey of 28 software implementations, including a commercial package called Power Calculus, which is being developed and marketed by a California Company called Digital Calculus. Their address is as follows:

Joseph Thames
Digital Calculus
Corporation
5406 Via del Valle
Torrance, CA 90505 U.S.A.

FAX (213) 791-1935,
TEL (213) 373-4827

I have since learned of a commercial C/C++ package distributed by a Canadian company called Otter Research,

Otter Research Limited
Box 265, Station A
Nanaimo B.C. V9R 5K9,
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A very comprehensive noncommercial package that does the forward and the reverse mode has been developed at Oak Ridge Lab over the last decade, the contact person there, is

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This package has been applied to a sizable number of nuclear engineering and other applications codes.

While I understand Louis Rall's frustration, the current situation is not quite as bleak as it looks to him. In the proceedings mentioned above there are several studies of large scale applications, some of which, like beam tracing in the SCC, could not have been done at all without AD. The collaboration between Argonne and Rice, which you alluded to, concerns the development of a new Fortran77 implementation called ADIFOR that is targeted for general sensitivity and derivative evaluations on complex models in scientific computing. The principal developers of this tool are my colleague Christian Bischof, Alan Carle of the compiler group at Rice, George Corliss of Marquette University, and myself. We have processed some very large "dusty decks" and the generated *enhanced* codes provide derivative information that often proved to be more reliable and much more accurate than previous methods for estimating sensitivities. Our long-term goal is large-scale design optimization, which is an almost ideal application for the reverse mode, provided there are not too many global constraints.

Automatic differentiation has many other potential benefits, including sharp estimates for the global effects of arithmetic errors and data uncertainties. This aspect has been thoroughly investigated by Prof. Masao Iri, who is at the University of Tokyo. [Reference to *Iri is given in* my report. He can be contacted as follows:]

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Copies of Griewank's papers on this subject can be obtained by contacting him directly.

INTERNATIONAL CONFERENCE ON ARTIFICIAL REALITY AND TELE-EXISTENCE, 1-3 JULY 1992, TOKYO, JAPAN

This articles reports on the 2nd International Conference Artificial Reality & Tele-existence, held from 1-3 July, Tokyo, Japan

David K. Kahaner

ICAT'92, the Second International Conference on Artificial Reality and Tele-existence, was held from 1 to 3 July 1992, in Tokyo. More than 150 scientists including about two dozen non-Japanese participated in this event, which is the largest international *virtual reality* (VR) conference held in Japan. Papers were presented in Japanese and English with simultaneous translation. The conference chair was:

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Professor Tachi is one of the key researchers in Japanese activities related to VR, see my report [vr.991, 9 Oct 1991], and [vr.791, 5 Sept 1991]. I have discussed some of his work in these earlier reports, therefore I will not repeat it. He presented a comprehensive paper detailing the current status of VR research, making the point that work is converging from various, initially independent, directions. Thus work on man-machine interfaces, teleoperation, realtime and computer simulation, art and holography, CAD, computer graphics, etc., have all evolved almost independently but now can be put to use to further the VR field. (ONR should note that important early work in teleoperation was done at the Naval Command Control and Ocean Surveillance Center, formerly NOSC, in 1983. Since then the research leadership has moved to other places.) Tachi distinguishes VR from tele-existence, although he admits that they are essentially the same things with a different point of view. VR enables humans to experience events and acts in a virtual environment just as if they were in the real world. Tele-existence allows humans, who are assumed to be emancipated from the restrictions of time and space, to exist in a *location* defined by inconsistent time and space, or a virtual space. Prof. Tachi provides a long list of potential applications of T-E and VR, but summarizes these by saying that they "will be the tools for 3Cs and 3Es, i.e., communication, control, creation; entertainment, education, and elucidation." He believes that todays motion sensors, including head, eyes, limbs, trunk, etc., are just the beginning of human measurement input that will occur. In the future these will be supplemented by EEG, EMG, blood pressure, pulse, perspiration, respiration, etc., which will be used to estimate human intent, and can then interface with either a real environment (such as a robot, aircraft, etc) or a virtual environment including even another virtual human. He also predicts that B-ISDN will be the vehicle that will make possible the connection between people and facilities, real and virtual, as well as makes possible the access to a VR database.

I have attached to this report the abstracts of all the papers presented at ICAT'92. My discussion focuses on the Japanese contributions although, in my opinion, the two papers that generated the most interest were both by Western authors, Bryson's description of a virtual wind tunnel based on experiments at NASA, and Becker's presentation of a high resolution head mounted display, (1120 × 900 pixels). Lack of resolution in head mounted displays

has been a constant complaint from researchers as well as users. Another interesting Western paper was by Marcus, who surveyed force feedback technology and in particular her own company's products specialized for the medical market. She made an intriguing point that it was her hope that VR was a good tool for representing phenomena that were normally imperceptible to humans. Most of the remaining Western papers related to amusements, art, products for entertainment, design issues, etc. emanating from a very strong entrepreneurial culture. The Japanese contributions tended to be more scholarly and academic. Some *almost* Japanese products were described (a tactile mouse was very interesting), but otherwise the emphasis seemed to be on studies, testing, engineering, etc.

ICAT ended with a panel on the status and future of this topic. All but one of the panelists were optimistic, although some were more practical than others. (Robinett (U-North Carolina) felt that VR was still a solution looking for a problem.) Jacobson (recently moved from U-Wash to his small VR company) felt that a broad appeal to business was needed, and that could occur if the use of VR to provide information solutions to information problems was emphasized. He also remarked that SigGraph has not served the VR community well; and that a more specialized professional society was needed. Marcus, at the other end of the spectrum, emphasized that there should be simple product focus, i.e., don't try to be all things to all people. Apparently her company EXOS, is successful, so her comments were taken very seriously by the audience.

The Japanese research community is heavily dependent on products and prototypes developed in the West. Just about all the VR hardware that is being used (except for items specially designed at university labs) is built by Western firms. Obviously, the technology to do this exists in Japan, but as yet the large electronics companies have not entered the field. Perhaps they will wade in while marketing consumer games using VR technology. What seems missing here is the spin-off from University or company labs that produces so many small low overhead shops (often staffed with ex-professors) striving to break into the market with a new idea. However, at least with respect to VR research, things seem to be getting better in Japan. Applications to communication and transportation are pushing the research along. VR's fad status has actually helped, and Japanese university research funding is improving. There was even talk of a VR research consortium, perhaps centered at Keio University.

Another key Japanese researcher is M. Hirose (U-Tokyo), who has been working on the development of a *virtual dome* (VD). Experiments have shown that while wearing a head mounted display (HMD), users need to have a visual field of view of 80 to 100° to provide realistic sensation; and updating that much information in real time is difficult. Hirose has been concerned about the appreciable time delay in updating scenes, when users move their head. This can give rise to discomfort and sometimes nausea. I have certainly experienced this while using some VR systems. The key principle of Hirose's VD is that the camera viewing the *real* scene and the human operator's head movements are basically asynchronous. Hirose uses a rotating camera unit, a communication unit, and a virtual space generator (VSG). In the latter, a virtual spherical dome is constructed via a set of polygons that are built from images taken by the camera. Images in the user's field of view are copied from the virtual dome to the HMD. This is a very clever system that involves the integration of three distinct parts in a sophisticated way, but that it has many opportunities for improvement including better image compression for transmission, the inclusion of 3-D (now only 2-D) and the integration of other sensors such as touch, auditory, walkthrough, etc.

One of the nicest prototypes was the force-display mouse, developed by scientists Akamatsu and Sato at the Industrial Products Research Institute. (Akamatsu was supported by ONR during a research visit to Marseilles France.) This is a simple mouse with a small hole in its top through which a short cylindrical pin (1 × 2 mm) can protrude from the inside. The up or down position of the pin can be controlled and hence can be programmed to coincide with position of a cursor on a screen. The pin is driven by a pull type solenoid via a lever mechanism. It is covered by a rubber film that is fixed to the backside of the press button of the mouse. This is used to return the pin to its rest position when the control signal is turned off. When the pin is in the up position, it is easily felt by anyone holding the mouse in a normal manner. (The pin has a stroke of 1 mm). The mouse is also enhanced by the use of a small electromagnet that can also be programmed to increase the friction of the mouse ball by about 12 to 15%. Together, the pin and magnet can provide tactile and force feedback. The authors' experiments asked users to move a workstation cursor and click on one of several displayed icons. They timed the responses, and also tabulated the number of *misses*. When the cursor is placed within the box, the pin is raised and the magnet is activated; both functions can easily be felt by the user. The effect is to

increase the assurance the user has about *landing* on the target, or equivalently reducing the time it takes to make such a hit, which were confirmed by experimentation. Improvements were about 10%. There is nothing fancy about this device, and we were told that its incremental manufacture cost relative to a conventional mouse is low. (The prototype mouse weighs 148 grams; a normal mouse weighs about 100 grams.) Of course, application software needs to be built to use these feedback mechanisms, but this seems fairly simple to do. The mouse was available for experimentation, attached to a mouse port on an NEC laptop. There was a big crowd around it and everyone was impressed that the concept really works. A definite winner. We were told that plans were already underway to develop a marketable version.

Moving through virtual worlds is done mostly by *flying*, but Iwata and Matusda, Tsukuba-U, are experimenting with a walking system. The user has his/her feet strapped to special rollers to simulate walking. The scientists feel that more realistic sensation of movement can occur in this way, but at the same time the equipment needed is much larger, and users are required to stand. Nevertheless they have performed some experiments suggesting that using such a system allows users to more accurately judge distance than by flying.

Buss and Hashimoto (U-Tokyo) are hoping to develop a virtual skill data base. The emphasis here is on a compliance model of motion through a sensor glove and a grip transformation matrix. Their sensor glove allows 10° of freedom, 3° for the wrist, 3° for the index finger, 2° for the thumb, and 2° for the rest of the fingers. This was a very interesting paper because the authors are thinking about automating skill acquisition, skill transfer, and assisted manipulation. As an example, they study a pen that is grasped by four fingers, in which the task is to move the fingers down the pen's length without breaking contact. It is definitely worth following the progress of this research. A related research direction, but with less sophisticated hardware, was presented by Ang [see the report "ia.92", 15 June 1992].

Toshiba scientists described what is in principle a very simple approach to displaying a 3-D image in space. Of course, one way to do this is by using holography, and Benton's (MIT) work seems to be out in front in this. The method proposed here uses a 2-D LED panel that vibrates perpendicular to its plane 30 times per each second over an extent of several centimeters. During its vibration, pixels on the panel are illuminated to represent cross sections of a volume. By careful choice of vibration time, number of section planes, type of LEDs etc., it is possible to give the impression of a 3-D object represented by its sections. By using an optical relay system the image can be visualized in an open space into which the user can place a pointing device and hence interact. At the moment only simple shapes can be represented, such as boxes and spheres. Although resolution is still quite low, the authors illustrated an application to displaying air flow in a room containing a small air conditioner and a table.

NTT scientists Suzuki and Kouno described their view of a virtual collaborative workspace. They object to the use of HMD display because, covering both eyes, facial expressions cannot be shown, and for a similar reason the immediate physical environment is not visible. On the other hand, HMD permits stereoscopic sensations. The approach they have decided to study uses a simple one-eye display that the user holds, something like half a pair of glasses, containing a color camera, a speaker, and a mike. They call this an intelligent handset (ScopeHand). The idea is that the picture seen by the covered eye tracks the movements of the user's face, thus making him/her feel as if he/she is using a large display of even multiple displays. For collaborative tasks, a wide workspace such as a conference table is needed to lay out materials. A camera is included in the handset, so pictures taken from it are from the user's point of view and show everything seen by the user. To realize a shared workspace, pictures of the table top and gestures of the user's hands as taken by his/her face camera are superimposed. In order to see faces, an external camera is placed where the *other party* would be. The picture of the partner's face is shown whenever the viewer looks directly at the external camera, in just the same way one would look at a person across the table. Of course, when you look at your *partner* you will see a partially obscured face, so Suzuki and Kouno performed some experiments to determine to what extent this detracted from the sense of understanding the other's expression. (ScopeHand is small but not trivial, 300 × 110 × 40 mm, and 450 g.) The scientists claim that the images from the handset are naturally fused with the real image from the uncovered eye and that masking a single eye is comparable to masking the mouth in terms of recognition of expression. Their approach is unconventional and interesting, but needs a great deal of work to become practical. I was surprised that the ScopeHand needed to be held, tying up one hand, and I wondered why it did not have a head mount of some kind.

NEC is also working on cooperative multiperson tasks, in particular using a collection of workstations on a network. Each user wears a VPL

DataGlove and a liquid crystal shutter eye-glass system enabling stereo display. Each user's workstation has its own 3-D virtual world, with objects having shape, color, location, direction of movement, etc. (Shapes are represented by splines.) Only one user at a time can grasp an object. This and other shared services are provided by an object management server that also initializes objects and manages all changes. The prototype applications here are CAD activities, so certain relevant functions such as object cutting and bending, color changing, etc. are implemented. The current system is running on a pair of Silicon Graphics IRIS-4D workstations plus one NEC workstation that acts as an object server. The authors comment that at present the workstations are connected by a Ethernet, but plan to reimplement their system by using a broad-band network to permit much faster interaction. This is yet another example of the trend in Japan to develop prototype products depending on the existence of high speed networks, such as B-ISDN.

For further details, copies of papers or the conference Proceedings, contact the authors, Prof Tachi, me, or the ICAT Secretariat.

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CENTER FOR COMPUTATIONAL PHYSICS AT TSUKUBA AND MPP

First description of a new Center for Computational Physics at Tsukuba University, with 300GFLOPS parallel massively computer.

David K. Kahaner

In an earlier report ["sacad.92, 1 July 1992], it was noted that a new computational physics center was being formed at Tsukuba University. The current report provides more details.

The scientists at the University of Tsukuba have many years of experience designing and using advanced computing equipment for physics calculations. I have reported on numerous occasions about the QCD-PAX and related parallel computers. QCDPAX was designed and built at Tsukuba specifically to perform the computations associated with quantum chromodynamics. Its architecture is that of a 2-D torus mesh, one of the first of this kind, and certainly the earliest practical mesh machine in Japan. Tsukuba scientists built special floating point controllers and used existing chips. Various versions of PAX have been built over a decade, and QCDPAX is the fifth of the PAX series. For parts of QCD computations more than 14 GFLOPS have been reported, making it one of the fastest QCD machines in the world. (In the spring of 1990, 480 processors (PU) were installed that achieved a peak speed of 14GFLOPS. However, most simulations are performed with 432 PU's to reserve some for replacing defective units. In this case the peak speed is about 12.5 GFLOPS.)

Other related projects are at Columbia University, NY, where a 16GFLOPS machine is running, at IBM, NY, with an 11GFLOPS machine, at the Fermi Lab, Illinois, with a 6GFLOPS machine, and an Italian project with a 1GFLOPS machine. In addition, a new project with hopes of producing a 100GFLOPS QCD machine is in progress in Italy, and new projects for producing even more than that are planned in the Unites States in collaboration with about 10 institutions that include Columbia University.

The PAX mesh architecture has proven to be useful for its intended computations, but current thinking is that a somewhat more flexible architecture is necessary for a wider range of physics applications.

One of the leaders of the PAX project was:

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Professor Iwasaki is now the Director of a new project, titled Center for Computational Physics (CCP) that began this summer at Tsukuba. Recently, I met with Iwasaki and reviewed the literature associated with CCP.

There are two essentially different funding programs. CCP is a ten-year project funded by the Japanese Ministry of Education, Mombusho, to bring together researchers to work in three specific areas of physics where computation is a key tool,

- Elementary particle physics
- Condensed matter physics
- Astrophysics and parallel computer engineering.

Fluid dynamics, which has been the bread and butter of large-scale computing facilities for many years, is not in the list. But Tsukuba physicists have highly developed expertise in all the areas above, especially the first. An expertise built upon their years of experiences with PAX, therefore they intend to concentrate on these topics. CCP will have ten full time Professors/Lecturers, including four new positions. About twenty well known computational physicists (not all from Tsukuba) are also listed as part of the project, but most will not participate full time. These include T. Hoshino (Tsukuba), who initiated the PAX project, and Y. Oyanagi (Tokyo), who contributed

heavily to many of the PAX machines. Iwasaki explained that CCP would have about ten students working with them, but their level (initially) will not be high. In addition, there are two new positions for guest or visiting scientists from other Japanese institutions. Iwasaki explained that there are mechanisms for facilitating foreign researchers to participate in the project, for example through the JSPS (Japanese Society for the Promotion of Science). CCP has just become operational, and there is, as yet, no additional space or building set aside for it. Iwasaki tells me that is one of his highest priorities.

Physicists working on CCP projects will need computational resources. At the moment they have access to the QCDPAX machine and also to supercomputer facilities at the KEK (High Energy Physics) lab. Fujitsu is placing five of its AP1000 parallel systems at Japanese universities, but not at Tsukuba, since access to high performance computing is not as good there as it should be. Additional power is also needed, which is to be provided by a new machine that is being separately funded as the major project administered by CCP. As a result of the QCDPAX experience, Iwasaki and his colleagues have decided that a *practical* massively parallel computer could be built with a few thousand nodes, each having several hundred MFLOPS peak computing capability, i.e., a total computing power of several hundred GFLOPS. Such a computer should have a few tens of GBYTEs of memory and perhaps ten times as much disk storage. It would differ from PAX not only by having a more flexible architectural design, but also by paying more attention to high performance input/output requirements, better peripherals, etc.

Because the PAX project is considered very successful, it was natural for Mombusho to try and build upon that effort, and it was decided to seek possible collaboration on a machine for related computing. Iwasaki explained to me that there were discussions not only with the major Japanese electronics companies, but also with some in the United States. In the end, the only company that elected to collaborate was Hitachi. Fujitsu and NEC already have active parallel computing projects, AP1000, and Cenju, respectively. In addition, Fujitsu has publicly announced an even newer parallel machine with performance on the order of 300GFLOPS, so they obviously have a plan in mind for development. On the other hand Hitachi, the largest of the Japanese *big three* has been virtually absent from the parallel computer field and clearly needed a vehicle. It seems likely to me that this could be the company's serious entry into the semicommercial market. This will depend on timing and how successfully the development proceeds.

Mombusho has funded this part of the project (i.e., the new machine) with about 1.5 Billion Yen (about US$12M) for five years. This is a very large project by Mombusho standards, and, in fact, it was one of only two large Mombusho projects this year. (My opinion (DKK) is that it might be difficult to purchase a commercial machine of this performance level within the given budget—hence the plan to design and build one—even though buying one, if it could be found, might have allowed more time for doing physics. I assume that Hitachi's activities, including their R&D are internally funded; thus, the actual project budget will be greater than that allocated by Mombusho. The total budget for the CCP project—non hardware—is not yet fixed and will be requested on a year-to-year basis, but in my opinion (DKK) it is likely to be comparable to the hardware part.) Hitachi and CCP scientists are working on the architectural design now, and it is to be finalized this year, so that a running system will be available by March 1996. That is likely to be an extension of the mesh concept that has been explored by PAX. But CCP scientists have already announced that their target is a 300GFLOPS machine with an unspecified number of processors.

Iwasaki explained to me that there will be active collaboration between CCP and Hitachi. CCP scientists (physicists and computer scientists) are now making a rough plan for the basic architecture of the MMP in hopes of having a design that will allow a highly sustained speed on application programs. Hitachi staff are also involved in these discussions. Hitachi will then provide the hardware and basic system software, such as software for send and receive, e.g., message passing. CCP will work on the application software. At the moment Hitachi's work is at three of their labs, but some consolidation is likely to occur. Iwasaki admitted that most physicists simply want to use standard languages and are reluctant to immerse themselves in low level language programming. It is possible that other groups at the University could make use of the new machine, but this is not yet been established.

Although the available details on this project are still quite sketchy, there is nothing unreasonable about their plans. 300GFLOPS by the mid 1990s should be achievable, especially as the machine is not really designed to be for fully general purpose use. It follows a trend that I have seen before here in Japan, of focusing on specific applications to drive

the development of new computers rather than on designing a general purpose system and then looking for users. The key CCP people are physicists and computer scientists that have experience in parallel computing. Thus, they have very specific ideas of the problems that they want to solve. Their track record with PAX is very good, and by obtaining assistance from a major computer manufacturer, they are likely to be successful in getting the machine they want on time. The missing element is the software base for parallel processing, which is not yet highly developed at Hitachi. It is likely that the company is viewing this as an experiment and also as a way of enlisting the assistance of a number of scientists who are already experienced with parallel computing.

STANDARD FOR THE EXCHANGE OF PRODUCT MODEL DATA IN JAPAN (PRODUCT MODEL DESCRIPTION STANDARDIZATION)

Japanese program activities in standardizing product descriptions, STEP, are described. The Japan STEP Center is the hub of activity in this area.

David K. Kahaner

A worldwide recognition is that more computer assistance is needed to be injected into the engineering design process. One aspect relates to how engineers can smoothly use traditional engineering CAD/CAM data along with other aspects of product data. For example, CAD/CAM data can describe idealized geometry, but does not describe the allowable tolerances, appearance, or material properties. One of the thrusts of work on several continents is to develop methods that will allow this kind of complicated and highly disparate data to be incorporated. There is work going on at several levels. Manufacturers of CAD/CAM software tools are implementing methodologies even when their definitions are not completely specified, standards setting bodies are wrestling with the issues of how to define and specify the requirements, researchers are studying conceptual problems in the abstract, and users are beating the drums for integrated and open systems. Thus a combination of advanced R&D as well as "right now" implementation exists.

CAD software vendors have developed their own proprietary solutions. Each major vendor has a format that engineers use for describing the details needed to input descriptions of product models. Data exchange between CAD systems is tricky since not all systems have the same features available (elliptical data elements available in one system might not be in another). Major efforts in the United States to develop standards for the interchange of CAD data between different vendors date from the early 1980s and have resulted in Initial Graphics Exchange Specifications (IGES), which has become an American National Standards Institute (ANSI) standard. Although IGES is evolving, new technology has prompted the development of a modern international standard rather than as an extension of an existing one.

ISO TC184 is the organization setting international standards in the area of industrial automation. It has several subgroups, including SC-4 that is concerned with standardized product descriptions (this is nicknamed ISO/STEP). SC-4 is chaired by Bradford Smith of United States National Institute of Standards and Technology (NIST) and has about 40 members. SC-4, in turn, has numerous working groups (Conformance testing procedures, Product modeling, Standard parts, etc.). The chair of the Japanese section of SC-4 is

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Professor Kimura was also the organizer of PROLAMAT'92, June 1992, Tokyo, as well as a workshop that followed on the topic of concurrent engineering, which is one of his primary areas of research interest. Summaries of these meetings are to be released later.

Modern product-description standards are being developed under a program called STEP (Standard for the Exchange of Product Model Data). Actually, STEP is the nick-

name for a set of parts documents that will become an ISO standard. In the United States there is also the PDES (Product Data Exchange Specifications), but this is now redefined to be "Product Description Exchange using Step", so it is now essentially equivalent to STEP. In the UK, France, and Germany the corresponding project/organizations are called CADDETC, GOSET, and ProSTEP; similar efforts exist in other countries also.

A great deal of cooperation and collaboration exit among these groups, including meetings four times each year and visits. To a greater or lesser extent, all are also competing to develop ideas, prototypes, and products, and to provide input to international and regional standardization organizations such as ISO. Since standard setting bodies accept one or another idea, they not only move the field forward, but also potential advantage is given to those organizations that developed and most actively promoted the concept.

Specifically, the STEP standard is a paper standard expressed in a programming-like language called Express that is the result of a long standardization process. Actually Express is a formal information modelling language (a conceptual schema as defined in ISO TR 9007) used to specify the details of the standard. Because it is given as a formal language, it can be parsed by computer, and thus the model so expressed can be manipulated in a variety of ways. In Express, entities are defined in terms of attributes, those traits or characteristics that are considered important for use and understanding. Attributes have a representation that might be a simple data type (such as integer), or another entity type. For example, a *geometric point* might be defined in terms of three *real numbers*. Names are given to the attributes that contribute to the definition and understanding of the entity. Thus, for a *geometric point* the three *real numbers* might be named x, y and z. A relationship is established between the entity being defined and the attributes that define it, and in a similar manner between the attribute and its representation. As a simple example, below is an Express specification for an entity called *line*.

```
*)
ENTITY line
SUBTYPE OF (curve);
  pnt : cartesian_point;
  dir : direction;
DERIVE
  dim : INTEGER :=
  coordinate_space(pnt);
WHERE
  wr1 : coordinate_
  space(dir) = dim;
END_ENTITY;
(*
```

If all of this sounds much like many other programming languages, it should. Express has freely borrowed from Ada, Algol, C, C++, Euler, Modula-2, Pascal, PL/I and SQL, but has also added features to make it more suitable for the job of expressing a standard information product model. Although Express is defined through a document in much the same way as Fortran is defined, it is not a complete programming language, but rather is a specification language (an unambiguous object definition with constraints on the data clearly and concisely stated). For example, it does not contain language elements for input/output, exception handling or standard information processing. Also, like Fortran, individual vendors can implement Express compilers with varying degrees of correctness, completeness, and efficiency.

The STEP product description standard is specified in Express, thus it is all on paper. Since there are many different vendor specific product descriptions, a major activity is to develop implementations that convert one to another by using STEP as an intermediate.

The Nippon Computer Graphics Association (NICOGRAPH) is a center of activity that corresponds roughly to the National Computer Graphics Association in the United States. NICOGRAPH assists in several ways. It is the focus of discussions by volunteer researchers from around Japan, providing facilities, secretarial support, etc. It also is the repository of the ISO standards relating to product descriptions. More interestingly, it is also the site of the STEP Center, a suborganization within NICOGRAPH, that occupies one floor of its building in central Tokyo.

The STEP Center was established two years ago as a four year industrial consortia in a joint industrial/governmental effort to promote the establishment and use of STEP in Japanese industry as well as to promote the use of CAD/CAM systems by taking advantage of STEP. In addition, it is specifically tasked to increase the contribution made by Japan to this technology. The Center is supported by eleven primary Japanese companies, each paying 10 million Yen per year, and another eight secondary companies that pay three million Yen per year each. In addition, MITI also provides about a third of the funding, so the total budget is slightly less than 250 million Yen per year, about US$2 M. The Center's official four year budget is about 900 million Yen. However, Kimura explained that (typical of such projects) the participating companies are expected to be active, at least within their own laboratories,

so the actual level of effort may be substantially greater.

In principle, each of the primary companies send an expert to work at the Center, but in practice it has been easier to get money than to get people. The current situation is that there are 3 to 4 company experts plus another 3 to 4 support staff. The secondary companies can have access only to the Center's output. Output to nonpaying organizations is held back for 2 to 3 years. The STEP Center Director is

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Dr. Kojima is partly responsible for the prototype development and is conducting the prototype implementation. He commutes to Tokyo about three days each week from his usual position at MITI's Mechanical Engineering Laboratory (MEL) at Tsukuba. (MEL and NICOGRAPH are doing a collaborative project related to the work at the STEP Center.) The role of academic researchers at the STEP Center is mostly peripheral; for example, Kimura is the chair of an academic advisory committee to the Center.

The Center's activities are twofold. First to engage in international cooperation for standardization in product description activities. Second, to perform data exchange experiments and develop a prototype STEP Processor as described below.

The STEP Processor is a program written in C, which takes as input files written in Express and produces as output files written in C++.

The input consists of three parts

1. A description of a specific CAD data model. By this we mean a formal description (in Express) of the language that a vendor requires in order to use their system. For example, a formal description of Hitachi's HICAD/DESIGN/W system, or Unisys's UNICAD/SOLID.

2. A description of the STEP data model. This eventually will be a complete and faithful formal description of the entire STEP model. The Center's policy is to create an exact implementation of STEP Version 1.0. The complete STEP data model is large, as it needs to deal with aspects of engineering design in diverse fields including, electronics, construction, shipbuilding, architecture, etc.

3. An algorithm that describes the conversion between STEP and the specific CAD model given in 1.

Presently, numbers 1. and 3. are implemented only for HICAD/DESIGN/W. (I was told by Kojima that this is directly related to available manpower, but further work is in progress.)

To repeat, all three parts above are written in Express.

The output from the Processor is a collection of files, specifically a conversion source program, a data-check source program, and a working form data (WFD) source program. (The Center's policy is that designs of any specific CAD system should be independent, and that all software will be developed on standard systems and using standard development tools. The demonstrations I saw were running on Sun Sparkstations. The use of exchanging data through the WFD files localizes CAD system dependencies.) There are also some files representing a symbol table of the entities involved in the conversion, i.e., definitions of attributes of symbols in the Express descriptions of STEP and CAD data models.

These files are not directly useful, but, when compiled by using a C++ compiler and executed, they produce a pair of processors (preprocessor and postprocessor). Thus the STEP Processor is a compiler-compiler. It is expected that the output compiler will be generated one, or a few times, but that the executable Pre/Post-processors will be used repeatedly.

The Preprocessor takes as input a physical product model file in the vendor CAD description, i.e., a description in HICAD/DESIGN/W of a specific product such as an airplane wing, and produces as output the corresponding description in STEP. The Postprocessor takes as input a STEP description and produces as output the description in a vendor specific language, such as UNICAD/SOLID. During both steps, appropriate checking for errors and inconsistent input occurs. This includes examining the CAD data for the physical model as well as for the STEP model.

Since the Center has already been in operation for two years, they have developed a phase I prototype that was demonstrated in April 1992. Kimura explained that it was not very interesting to see, and suggested that I wait for better examples. He also pointed out that the research is still very preliminary, and will probably take three to five additional years to really bare fruit. Unfortunately, he feels that Japanese industry misunderstands the difficulty associated with the research and has been expecting practical results from the Center too quickly. Nevertheless, I visited Dr. Kojima at the STEP Center and was shown one demonstration by him and Mr. Yutaka Kugai,

who is a Sharp Co. researcher stationed at STEP.

The Center's development schedule is as follows (years mentioned are fiscal years, e.g., 1992 FY is from 1 April 1992 to 31 March 1993).

- Basic design of STEP system, Express Processor, standard function library including access to WFD: finished by end of 1991, but supplementary work continues through 1992.
- Geometric conversion library (such as curve and surface conversion) begun in 1991, finished by the end of 1992, but supplementary work continues through 1992.
- Experiments with various geometries, 2-D geometry to be completed by the end of 1991, curve and surface geometry work to continue through the end of 1993.
- Testing to continue through the end of 1993. During 1992 and 1993 FY, experiments will focus on free-form surface data and drafting data. Drafting data exchange is claimed to be the area in most demand from CAD/CAM users, and the area where the IGES data exchange is particularly weak.

Project plans for the next two years are to enhance the STEP Processor so that it has a more complete STEP model (now just a proper subset) and perform major testing.

The Center's staff points out that their prototype system has generated the following kinds of comments.

1. Development support tools for using Express need to be improved.
2. Conversion speed (compared to vendor specific products) is slow.
3. Users have difficulty in generating the input and output part of the CAD physical file by using Express descriptions.
4. Automatic generation of conversion algorithms from data model are needed.
5. Potential for data exchange via database needs to be explored.

One test that the Center's staff has undertaken and described in detail is the conversion of a model of a telephone handset from HICAD to UNICAD through STEP. The document,

> Supplement: A Report on a Data Exchange Experiment by Japan STEP Center, Nicograph
> 22 April 1992

is available from the STEP Center (write to Kojima). I can also supply a copy to interested readers. This gives complete breakdown of the conversion and data exchange procedure, including schema and entity definitions (STEP, HICAD, and UNICAD), STEP/CAD conversion schema, STEP class definitions (in C++), exchange files (HICAD, STEP, and UNICAD). Also included are tables giving data and program file sizes as well as performance figures for all parts of the exchange process.

Converting from one vendor's CAD descriptions to another's is a very time consuming operation that requires minutes or hours of workstation time, and implementation efficiency is a prime consideration. Thus, vendors try to produce tuned programs that make such conversions. Kojima pointed out that their STEP Processor will not compete with these implementations, but believes that their approach is very flexible and gives the vendors experience with STEP with little effort. In the demonstrations that Kojima and Kugai showed me several minutes of Sparkstation time were required to process a simple product description for a telephone handset. Kojima explained that vendors could reduce this time by about one order of magnitude by using specific implementations, but that performance was not an issue for the prototype system they were working on.

At the conclusion of the four-year project MITI has in mind a reorganization that will bring in many more companies, 50 to 100 (although each company will make more modest contributions), and allow Japan to make a greater contribution to international standards. Kojima explained that the STEP Center might go out of existence at that time, but more likely it will continue. Kimura made an interesting analogy between STEP and the ICOT (Fifth Generation Computer Project). The latter was a large 10-year project. During the first five years of the project, the ICOT organization succeeded in training a large number of Japanese researchers in the concepts of logic programming. After, these people went back to their companies to develop their own specialized products and to introduce the technology to their laboratories. While this had a very positive impact within Japan, it had the effect of reducing the impact of the ICOT centered development during the second five years. Kimura feels that a similar thing may happen for the STEP Center.

In summary, while STEP is a very international activity, the Japan

STEP Center Processor is unique in that it is an *exact description* of STEP, and also in its efforts to be CAD-vendor as well as computer system independent.

A reference for international details about IGES, PDES, STEP and related activities in computer integrated manufacturing and construction is the newsletter, "Product Data International", ISSN 1050-7043, edited by Barbara D. Warthen (619) 942-8194.

STEP CENTER MEMBERS:

Class 1 Members (can participate in implementation activities, and use results for internal use as well as for commercial products)

- Oki Electric Industry
- Nippon Steel
- Sharp
- Toshiba
- Nissan Motor Co.
- Nippon Electric Co.
- Nihon Unisys Co.
- Hitachi
- Fujitsu
- Mitsubishi Electric
- Yokogawa Electric

Class 2 Members (can participate in technical committee regarding implementation and use results for internal use)

- Ishikawajima-Harima Heavy Industry
- Hagiwara Ironworks
- Komatsu
- Sanyo Machinery Co.
- Toyota Motor Co.
- IBM Japan
- NKK
- Ricoh Co.

VISIT TO JAPAN BROADCASTING CORPORATION SCIENCE AND TECHNICAL RESEARCH LABORATORY AUGUST 1992

Report of the Visit to NHK Science & Technical Research Laboratory, August 1992

David K. Kahaner

In an earlier report ["3d-2-92.1", 21 Feb 1992] I explained the general themes of NHK's (Japan Broadcasting Corporation) research directions, also I described a few of the specific research projects that I saw during a visit in early 1992. Recently, I was able to revisit the NHK Science and Technical Research Labs to have a look at some other projects. (The visit was in the company of Dr. S. Yamamoto, the ONR Asia Office Director, who has collaborated with me in the current report.)

Without trying to repeat the overview material given earlier, we note that NHK is the Japanese public broadcasting organization. The S&T Research Labs are where the NHK's main research is done. It was established in 1930 and currently has a staff of 330 (270 scientists) and an annual budget of 7 Billion Yen (a little more than US$50M). This represents slightly more than 2% of NHK's total employees and about 1.5% of its total budget. (Laboratory sizes have to be judged by Japanese standards—this is considered a large laboratory, perhaps comparable to an organization of twice its size in the West.) The research themes of the Labs cover a wide range of broadcast technology from basic research in audio-visual science, materials and solid-state physics to the development of broadcast equipment and systems. Activities are aimed at three major research goals, a. *new broadcast services*, b. *improving existing broadcast services*, and c. *basic technology to support future broadcasting*. A large part of NHK's activities are related to direct satellite broadcasting (DSB) and Hi-Vision (HDTV of Japan). DSB began 24-hour service in June 1989 on two channels. Currently, there are eight hours per day of Hi-Vision DSB programming. DSB means that individual users can purchase a small antennadish—approximately 15" in diameter for as little as US$150, and receive satellite programming on their home TVs. The Japanese BS-3b satellite has a traveling wave tube (TWT) that permits about 120W of power output, thus permitting these small diameter antennas. Such dishes are extremely numerous in Japan; they are commonly attached to balcony railings and window ledges as well as on rooftops. A great deal of antenna research done at NHK is related to this, for example shaped on board antennas as well as flat-panel and auto-tracking antennas for receivers.

A very large amount of Hi-Vision TV is being made available (in Japan) from the Barcelona Olympics. Special Hi-Vision cameras feed to compatible VTRs, which, after coding, feed via satellite and ground link to Japan. Signals are eventually routed to one of the broadcast satellites (BS-3b) from which signals can be received by the small home dishes (BS-antennas) mentioned above. A special BS tuner is required (available on many home TVs here in Japan and not expensive), and also a Hi-Vision decoder (MUSE) that is expensive. After decoding, the signals can be displayed on a Hi-Vision TV. A 36-in. diameter Hi-Vision monitor costs about US$20,000; the decoder is about another US$10,000. Panasonic, Hitachi, Toshiba, Sharp, Sony, NEC, JVC, Pioneer, Mitsubishi, Sanyo, and other vendors have such products. The price is still far too high for ordinary users but a substantial number of systems are in commercial use for demonstrating products, in museums, etc. Prices are expected to drop rapidly, and the large volume of programming will certainly pique home viewers interest. Personally, I can attest to the extraordinary impact of the Olympic events, when viewed on a large screen in this high definition format.

Direct Broadcast Satellites are widely accessed here, even for non-HDTV. NHK is looking for new services making use of DSB. One such service could be broadcast-

ing high definition still pictures and sound, for potential use in pictorial and photographic art programs and detailed information programs for catalogs. Various standards groups are working toward a standardized high-efficiency picture coding scheme for such still pictures. The current approach to picture coding is by use of the discrete cosine transform (DCT). By adjusting the coding parameters good picture quality as well as audio can be transmitted through the data channel of existing satellite TV broadcasts. An uncompressed high definition still picture is about 4 Mbytes. Based on the capacity of the data channel of a broadcast satellite, it would take about 90 s to transmit the original picture and some stereo sound, but by using the DCT and a little picture quality degradation, this can be reduced to 1 to 5 s (depending on the image). Since both still video and audio can be put onto a DAT (digital audio tape) this is seen as a nice *package* service. This is an interesting application that makes use of what is currently unused capacity in existing satellites.

The Japanese Hi-Vision system is an analog system, whereas plans in the United States are for an all digital HDTV system. The latter is claimed to be much more flexible and is thought to represent more advanced technology. Neither Yamamoto nor I are experts in any significant aspects of TV broadcasting, but we were curious about this and asked our NHK hosts for their views.

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Their opinion was that definitely, digital high definition TV was clearly the direction of the future, and there was plenty of work in progress at NHK along those lines. But many technical problems remained to be solved, including the very serious one of digitally reducing the amount of data that was generated at the source, and they are not expecting a significant infiltration of digital receivers until next century (10-15 years was the estimate that our hosts gave us, before analog HDTV is replaced by a digital system). In the meantime they feel that while there are many technical issues that are unique to digital TV, there are also others that overlap with analog technology, and the Japanese are working to address these right now. Furthermore, problems of infrastructure, programming, and culture, will not be so different between the two technologies, and experience gained now will be useful for the future also. In other words these scientists did not seem concerned about being *jumped* by Western technology since they follow their own course.

During this visit we had the opportunity to see four specific research projects. These are described below.

Superharp (Ultrahigh Sensitive Camera Tube)

In 1987, NHK and Hitachi announced that an experimental camera tube had exhibited high sensitivity with a quantum efficiency greater than one, because of a multiplicative effect resulting from a high-target electric field of 240 V. This was about ten times as sensitive as conventional camera tubes and gave a burst of life to research in camera tubes that many believed would soon be replaced by solid-state imaging devices such as CCDs. Very recently NHK and Hitachi have improved the sensitivity by another factor of ten, thus resulting in what they have called the Super-HARP tube (High-gain Avalanche Rushing amorphous Photoconductor). The 18-mm tube has a target size of 6 μm (three times that of the original HARP), necessitating a corresponding increase in the imposed electric field (to about 640 V) to maintain an electric field of the order of 10^8 V/m required to produce the multiplicative effect.

In addition to increasing sensitivity the delay lag has also been reduced by about two thirds. This is the time lag in the field after incident light has been turned off; viewers observe this as streaks that remain on the TV image when a bright light source is moving. NHK scientists believe that the lag can be decreased even further.

The current SuperHARP tube has a resolution of more than 800 TV lines and is limited by the size of the electron beam. In other words if electron optics for HDTV were used, resolution could be increased further.

We were shown a live demonstration of this new camera in a side by side comparison with a traditional SATICON color camera both viewing the same indoor scene. In the latter case, the TV image was almost totally black, while the new camera image was clear, sharp and brilliantly colored.

We also saw a video made with the new camera of various astronom-

ical events such as nebula and aurora. Applications to underwater and other dark scenes were also mentioned and are obvious. In a related application we were shown a beautiful video taken by a HDTV (ordinary) HARP camera from the top of Moana Loa during the recent solar eclipse. Striking details of solar prominence were clearly visible.

Autostereoscopic 3-D Television Display

In the report referenced earlier, this device was also briefly discussed. NHK scientists and most other researchers in this field, within Japan, believe that any future 3-D TV display must be a *glassless* system in order to be accepted by home viewers. Several projects are inexorably moving forward in this direction. Lenticular screens are well known from 3-D *post cards*. These screens consist of an array of half cylindrical lenses. In the TV application, stripe images from 3-D TV cameras are displayed behind the screen to match the screen's pitch and 3-D images are then visible from different viewing points. There are a great many complex aspects to this approach. NHK has been working on flat-panel display devices because of their ease of optical alignment and a 12-in. PDP (plasma display panel) has been developed for viewing images from four cameras. In addition a 9-in. EL (electroluminescent) display with input from five cameras has been built. A large, 40-in. LCD projection TV display has also been built for viewing images from two cameras.

Finally, there is a 50-in. rear-projection TV display. This is a joint project of NHK, Sanyo, and Toppan Printing, with Toppan building a new "hollow" lenticular screen combining sections of glass and air. NHK claims that the combination of different refractive indices shorten the focal length for incident light, resulting in increased light transmission and reduced screen thickness leading to a weight reduction of about two thirds. When I saw this system in January 1992, four cameras were used to supply images. Thus viewers effectively had four views that put together generated an interesting but not spectacular image. Since then, the number of cameras have been doubled to eight. The camera lenses are essentially touching so there is not much room for further improvement here without major optical changes. The resulting image is also much improved in its 3-D quality, while remaining bright and highly viewable. Seating position is still constrained both as to distance from the screen and lateral movement, but the additional cameras made the image more interesting to me and reduced the need to shift my head as much as before. The 50-in. screen has an HDTV aspect ratio of 16:9 and the LCD panel has 1440 × 1024 pixels with three colors. It is adequately bright to watch under normal room lighting.

Lightweight Nearly-HDTV Camera

HDTV cameras are very expensive. In addition, their size, weight, and battery drain make them less convenient to use than conventional TV cameras. One interesting experiment that NHK scientists are engaged in is to see what compromises can be accepted in visual quality that lead to significant reductions in size and cost. The most interesting of these is a 2/3 in. (detector) camera with a total of 3.9 million pixels within the detector, but not evenly divided among the three primary colors. Instead, 2.6 million pixels are used to detect green, the remainder pixels for the other colors. (This choice was based on experiments with human visual sensitivity.) The resulting camera is almost the same size as a standard professional TV camera, but much smaller than a conventional HDTV camera. We were shown live indoor pictures from the new camera, and these were (to us) as good as HDTV images, and clearly superior to standard images. NHK claims that much smaller batteries can be used, and that the lightweight and small size translate directly into cost savings. They expect that these cameras can be priced at half of a conventional HDTV camera. They also explained that these cameras are used at the Olympics in Barcelona for their first significant field test.

Desktop Program Production

This is a clever synthesis of multimedia technologies to produce an integrated working environment for TV program production. Maintained on some databases are computer graphics images of various *sets* as well as components such as tables, bookcases, etc. On separate video disks are moving images of *actors*. In the case of the current system the latter are real video, although they could easily be animated. The user of such a system can create a virtual studio set using real-time computer graphics to access, process, synthesize, and edit all the audio and video. On an attached workstation, not only the time-coded VTR tapes but also other attributes such as virtual camera position, object shape, and lighting, can be managed. A usual TV editing system can manipulate audio and video, NHK can make changes in these other attributes as well. The current system was shown to us with two 2-D actors, and one 3-D actor. The most interesting aspect of this work was that it operates in real time. To do this, NHK has built a video-rate processing system for

NTSC signals (called Picot) composed of several processors connected in parallel to allow fast image generation, motion adaptive correction, geometrical transformations, video synthesis, by software. Unfortunately all the hardware was disassembled during our visit, and we were only shown a video of a typical editing session. But NHK is currently developing a higher speed processor for Hi-Vision signals. The software is written in C on a standard multimedia workstation. The project involved nine scientists over three months for the software aspects, and work over more than five years for the hardware development.

A related activity that we did not see but were told about is called Synthevision. This processes background stills and motion pictures digitally, and allows them to be synchronized to the panning, tilting, zooming, and focusing of a live camera. Backgrounds can be generated by computer graphics to eliminate studio sets. NHK notes that as backgrounds can be changed electronically, the operational costs of studios can be reduced. There is also experimentation of "pseudo" 3-D by using multilayered images at different depths and synchronized to a camera dolly's movement.

I would like to thank Mr. Hayashi and Mr. Tetsuhashi as well as numerous other NHK scientists for their assistance during our visit and also in the drafting of this report.

NAVIER/STOKES SUPERCOMPUTER BENCHMARK—AN UPDATE

In 1989 the Cray YMP-8, Fujitsu VP-4OOE, Hitachi 5-820, and NEC SX-2 were benchmarked on a delta wing flow using the Reynolds-averaged Navier/Stokes code [1]. The present update extends the benchmark to include the Cray YMP-C9O, Fujitsu VP-26OO/1O, and NEC SX-3/14. Since the Cray YMP-8 that benchmarked earlier was a test prototype with a cycle time of 6.4 ns, a production model YMP with a cycle time of 6 ns was also included in the update.

by Kozo Fujii and Hideo Yoshihara

INTRODUCTION

There has been a phenomenal increase in the power of supercomputers during the past half-decade. The increase was accomplished in part by the rapid advance of computer hardware, but computer architecture also played a significant role. Peak speeds were increased by carrying out computations concurrently employing many parallel vector arithmetic processing pipes in each central processing unit (CPU) and incorporating many CPUs. The trend in Japan has been to install many (8 to 16) parallel processing pipes into a single CPU computer. The trend in the United States, on the other hand, has been to use many CPUs, each CPU having few pipes. A key difference in these two approaches is that the many pipes in the 1-CPU computer have only one instruction path and must accordingly carry out the same calculation. On the other hand, each set of pipes in different CPUs has its individual instruction path, so that different calculations can be carried out concurrently in each pipe set. An intent of the benchmark will be to show the consequence of this difference in architecture.

Instead of the usual arithmetic kernels, the present benchmark used a typical fluid dynamic problem to measure the computer performances in an applied fluid dynamic scenario. Here a delta wing flow using the Reynolds-averaged Navier/Stokes code was employed.

The benchmark results will also be included as part of Ref 2.

DETAILS OF THE BENCHMARK

The flow over the delta wing was calculated by using a structured grid with dimensions 119 × 101 × 71. The Obayashi/Fujii alternating-direction implicit (ADI) code (typical of those used in the United States and Europe) was used, which entails solution of many systems of simultaneous nonlinear algebraic equations. The coefficient matrix is either upper or lower tridiagonal. The solution was obtained iteratively by successive approximation.

The benchmark calculations were carried out by these personnel from the participating companies. (Table 1).

Table 1 — Benchmark Calculations by Participants

Cray Research Inc.	Mr. K. Misegades and Dr. T. Saito (Tokyo)
Fujitsu Ltd.	Mr. N. Tahara
Hitachi Ltd.	Mr. S. Kawabe and Mr. K. Ishii
NEC Corp.	Mr. S. Mineo and Mr. Y. Kobayashi

The following cases comprised the benchmark:

Case 1
200 iterations by using the code furnished with the standard compiler

Case 2
Fortran-compatible directives additionally permitted

Case 3
Code modifications additionally permitted.

Computations with one and multiple CPUs were carried out in the case of the Cray computers.

SUPERCOMPUTER CHARACTERISTICS

In brief, features of the benchmarked computers are shown in Table 2.

Comments on the above characteristics are appropriate. First the peak speed in GFLOPS is defined as the total number of processor pipes (both add and multiply) divided by the cycle time in nanoseconds. That is, the processor pipes are assumed to be operating continuously without any overhead, producing one FLOP each cycle time. Actual sustained speeds in a given computation will thus be a fraction of the peak speed.

In the case of the Fujitsu VP-2600 each pipe of the chained pair was assumed to be independent, so that the total number of pipes was taken as 16 in the calculation of the peak speed. In the benchmark problem the operations were primarily dyadic (simple adds or multiplications), so that one of the pipes in the chain was usually idle. A more realistic number of independent pipes would then be eight, and the peak speed for the VP-2600 for the benchmark would be closer to half the brochure value, namely, 2.5 GFLOPS.

The significance of $M/R_{1/2}$ is that it serves as a measure of the fetch pipes to provide numbers in a timely fashion to the processor pipes assuming the pipes to be operating at one-half peak speed. Ideally a value of $M/R_{1/2} = 3$ W/FLOP is desirable to provide a fetch of two numbers for a dyadic operation and a store of the result for each FLOP. This would suggest that the Cray YMP computers would have adequate memory/register bandwidth, whereas the Fujitsu VP-2600 and NEC SX-3 would have inadequate bandwidth. The apparent inadequacy in the VP-2600 is however moderated by the overlapped fetch instructions permitting successive vector fetches to proceed without interruption and additionally having large capacity vector registers where numbers can be "stockpiled" in advance of the calculation. It is clear that the above memory/register bandwidth requirement would be less if the pipe were operating at less than one-half peak speed.

Another important feature of the computers not listed above is the capability of the compilers, namely the versatility of the autovectorizers and the autotasker, the latter in the case of the Cray multi-CPU computers. The autovectorizer rearranges the code to maximize the calculation in an "assembly-line fashion." Fluid dynamic codes are, in most cases, highly vectorizable. The autotasker identifies independent portions of the code and assigns their calculation to the different CPUs in such a way that CPU idle time is minimized. The benchmark speed will depend not only on the compiler performance but on the degree to which the code can be vectorized or parallelized.

BENCHMARK RESULTS

Performance in the benchmark was measured in terms of two quantities. The first is the sustained speed of the calculation that is of interest to the user, since it is a factor determining cost and turnaround. Sustained speed is determined by dividing the operation count of the problem by the elapsed time, the former obtained from the YMP calculations. The second is the sustained/peak speed ratio, which is a reasonable basis to compare the computers. It also measures the efficiency of the computer for the benchmark problem.

In the case of the multiple-CPU Cray computers, the ratio of the elapsed times with one CPU and multiple CPUs was also given. It is a measure of the parallelization efficiency of the computer/code combination. It is desirable to have this ratio close to the number of CPUs.

The benchmark results are compared in Table 3.

Table 2 -- Computer Benchmarked Features

Cray YMP-8 (8 CPUs)	
Cycle time	6.0 ns (ns = nanosecond)
No. proc. pipes	1 add + 1 multiply per CPU
Peak speed	2.67 GFLOPS (total) (GFLOPS = million (giga) floating point operations per second)
Memory	1024 MB (MB = megabytes)
Mem/reg bandwidth	42.4 MB/s
$M/R_{1/2}$*	4 W/FLOP (8B = 1 word)
Cray YMP-C90 (Benchmarked Prototype 15 CPUs)	
Cycle time	4.2 ns
No. proc. pipes	2 add + 2 multiply per CPU
Peak speed	14.28 GFLOPS
Memory	4096 MB
Mem/reg B/W	240 MB/s
$M/R_{1/2}$	4W/FLOP
Fujitsu VP-2600/10 (1 CPU)	
Cycle time	3.2 ns
No. proc. pipes	8 chained multiply/add combination pipes
Peak speed	5.0 GFLOPS
Memory	2048 MB
$M/R_{1/2}$	1 W/FLOP
NEC SX-3/14 (1 CPU)	
Cycle time	2.9 ns
No. proc. pipes	8 add and 8 multiply
Peak speed	5.5 GFLOPS
Memory	2048 MB
$M/R_{1/2}$	1 W/FLOP

*$M/R_{1/2}$ = Number of words transferred from memory to register per FLOP with the CPU operating at one-half peak speed.

Table 3 — Benchmark Results

Computer	CPU Time (s)	Elapsed Time (s)	Sustained Speed (GFLOPS)	Sustained Peak Speed Ratio
Cray YMP-8				
Case 1				
1 CPU	2813.0	2834.0	0.215	0.64
8 CPU	3032.0	1529.0	0.399	0.15
Case 2				
8 CPU	2915.0	402.0	1.52	0.57
Cray YMP-C90				
Case 1				
1 CPU	938.0	969.1	0.644	0.697
Case 2				
15 CPU	1153.6	79.0	7.90	0.553
Fujitsu VP-2600/10				
Case 1	431.3	435.2	1.40	0.28
Case 3	276.5	281.7	2.19	0.44
NEC SX-3/14				
Case 1	534.8	553.9	1.13	0.21
Case 3	288.2	295.3	2.10	0.38

Figure 1 also shows the sustained speeds and sustained/peak speed ratios. Also, autovectorizers in all computers performed in an outstanding manner with a near-100% of the code being vectorized.

Notable in the above results were the following:

Cray YMP-8 and -C90

The 1-CPU sustained/peak speed ratios of 0.64 for the YMP-8 and 0.697 for the YMP-C90 are outstanding, attesting to the overall well-balance of the computer architectures. The 8-CPU Case 1 performance of the YMP-8 is surprisingly poor, pointing primarily to the inadequacy of the autotasker to parallelize the code properly. This was confirmed by the 8-CPU Case 2 performance, where several easily implemented autotasking directives greatly improved the performance. Here the directives primarily identified the parallelism in the outer loop that the autotasker could not identify.

The 1-CPU/8-CPU elapsed time ratio for the YMP-8 was 7.05 (that is, 88% of 8); for the C90, it was 12.27 (82% of 15). This outstanding multi-CPU performance was due not only to the directive-augmented autotasker but to the degree of parallelization residing in the code.

Fujitsu VP-2600

The sustained/peak speed ratio of 0.28 appears at first glance to be very poor, but it must be recalled that the brochure peak speed of 5 GFLOPS is unreasonable for the present benchmark where dyadic operations predominate. In this case the peak speed

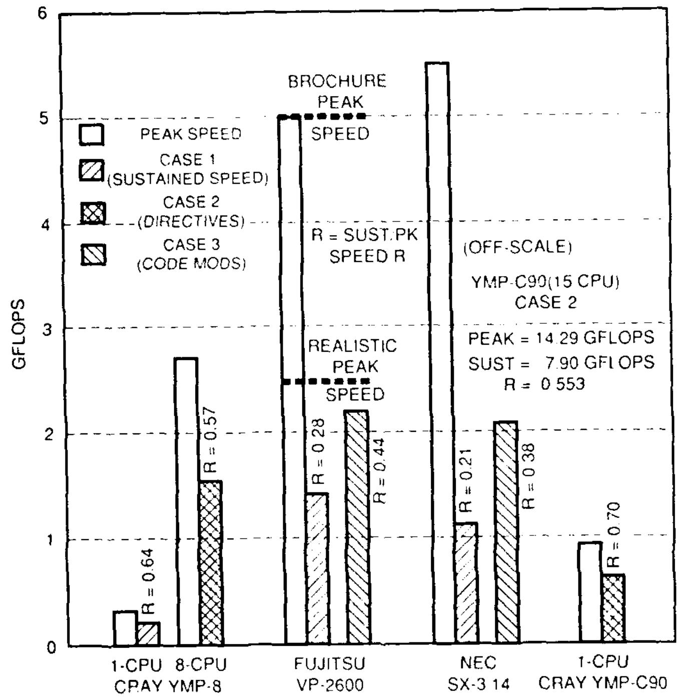

Fig. 1 — Sustained and peak speed comparisons

is more realistically half the brochure value, namely 2.5 *GFLOPS*. With this peak speed the benchmark sustained/peak speed ratio would be a respectable 0.56. It would then appear that the overlapped fetch/store instructions, together with the large vector registers, have compensated for the low memory/register bandwidth.

Another factor degrading the sustained/peak speed ratio is the processor pipe overhead, which arises from the passage time of the initial floating-point calculation through the pipe. This pipe overhead can be made insignificant if it can be amortized over a sufficiently large number of calculations—that is, over a sufficiently large vector length. In the case of the VP-2600, the vector length must be spread over eight processor pipes, thereby greatly reducing the vector length per pipe and worsening the pipe overhead. (Note that in the YMP computers with two pipes/CPU the vector length reduction is significantly less.) The increase of the pipeline overhead due to the decreased vector length is confirmed by the Case 3 results, where the vector length increase by the double- and triple-loop unrolling increased the sustained/peak speed ratio from 0.28 to 0.44. Such DO-loop unrolling is generally discouraged by computational fluid dynamic programmers since the consequence is an untidy code that is difficult to maintain.

NEC SX-3/14

The sustained/peak speed ratio of 0.21 was disappointing and clearly due to excessive pipe overhead with the 16 pipes. Undoubtedly the inadequate memory/register bandwidth was also a contributing factor. Double- and triple-loop unrolling are also contributing factors. Double- and triple-loop unrolling also improved the sustained/peak speed ratio to 0.38, again confirming the large pipe overhead in Case 1.

The 4-CPU SX-3/44 will be available in the near future. The multiple CPUs should improve the SX-3/14 performance in the benchmark, but it will be extremely difficult to overcome the effects of the excessive pipes per CPU and the low memory/register bandwidth.

CONCLUSIONS

Two significant factors that degraded sustained/peak speed ratio in the single CPU computers were the processor pipe overhead and an inadequate memory/register bandwidth. In the alternating direction implicit (ADI) Navier/Stokes code used in the benchmark, the nominal vector

length was of the order of a mesh dimension. Such a code is thus unsympathetic to a many-pipe 1-CPU computer. The processor pipe overhead could be reduced greatly by using a more sympathetic code as an explicit code, where the vector length is equal to the total number of mesh points. The penalty arising from an inadequate memory/register bandwidth, on the other hand cannot be readily circumvented.

Results of the benchmark suggest the superiority of the few pipes per CPU/multi-CPU architecture over the many-pipe/1-CPU design from the point of view of the sustained/peak speed ratio. Having multiple CPUs would additionally enhance the job throughput.

As with any benchmark a note of caution is in order. The present results cannot be claimed as representative even for fluid dynamic problems. In the narrower class of Navier/Stokes codes, use of an explicit code, for example, would lead to very different relative performances than reported here.

Finally, one cannot avoid being impressed by the demonstrated power of all the benchmarked computers, due both to the speed of the hardware components and to the capability of the compilers. A sustained speed of at least 1 GFLOP was achieved by all computers, that is, at least one billion adds or multiplies per second.

ACKNOWLEDGMENT

The authors express their appreciation to the benchmark participants and the management of Cray Research Inc., Fujitsu Ltd, Hitachi Ltd, and the NEC for making the benchmark possible.

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Hideo Yoshihara served as a liaison scientist for the Office of Naval Research Far East from April 1988 until May 1990. His assignment was to follow the progess of advanced supercomputers and to review and assess the viscous flow simulation research in the Far East. Dr. Yoshihara formerly was with the Boeing Company, where he was Engineering Manager for Applied Computational Aerodynamics. He was also an affiliate professor in the Department of Aeronautics and Astronautics of the University of Washington, an AIAA Fellow, and a former member of the Fluid Dynamics Panel of AGARD/NATO. Dr. Yoshihara is now retired.

SLOW DYNAMICS IN CONDENSED MATTER

The first Tohwa University International Science meeting was held in Fukuoka (Japan) during November 1991. The focus of this meeting was devoted to slow relaxations in glassy materials. Many different materials were found to have similar characteristics near their glass transition.

by Michael Shlesinger

Tohwa University in the Fukuoka Prefecture (Japan) has made a commitment to organize an international meeting each year. The first meeting to be held was ours on "Slow Dynamics in Condensed Matter." It is interesting that 16 sponsors attended. Some of these, besides the Physical and Chemical Societies of Japan, included the Mainichi and Nishinippon newspapers; the Japan, Fukuoka, Kyushu Asahi, and RKB-Mainichi Broadcasting Companies, TV Nishinippon Corp.; and Nippon Telegraph & Telephone Corp.; Nishi-Nippon Railroad; and Gakujutsu Tosyo Publishing. The proceedings of the meeting will be published as American Institute of Physics (AIP) conference proceedings #256 "Slow Dynamics in Condensed Matter" edited by K. Kawasaki, M. Tokuyama, and T. Kawakatsu.

SCIENTIFIC REVIEW: THE TOHWA UNIVERSITY MEETING

Slow Dynamics in Condensed Matter

Much of physics can be cast in the form of finding a definite answer, perhaps with error bars. Some questions, especially for the study of disordered materials, involve finding a distribution of possible results, instead of a single result. For disordered materials, one seeks, in one form or another, the relevant time scales. When the distribution of time scales is broad enough, such that it is not well characterized by its first and second moments, then no single time scale dominates. Examples of this occurrence are in dielectric relaxation and mechanical relaxation in glassy materials. It is the appearance of longer and longer time scales that ruins the simple characterization of physical processes in amorphous glassy systems. In this context the dynamics is called "slow". Understanding the physics behind slow dynamics in glassy materials was the topic of this conference.

About 250 participants attended the meeting representing 15 countries. The largest contingent of participants was from Japan. Korea was the only other Asian country to attend. Most of the other participants were from the United States and Western Europe.

One dominant theme of the meeting was to explore the validity of mode-coupling theory to explain slow relaxations. The major proponents of this theory, W. Gotze (Technische Univ., Munchen, Germany) and L. Sjogren (Chalmers University, Goteborg, Sweden) presented papers at the meeting. Mode-coupling theory is a general treatment of atomic scale motions that are decomposed into Fourier momentum modes. The basic assumption is that the slowing down of dynamics near the glass transition is governed by density fluctuations. The basic equations couple the modes through nonlinear terms. One writes the density correlations in terms of a frequency dependent viscosity that, in turn, is written as a series in powers of the density correlation. The basic idea is to lower the temperature in the theory, see if interaction length can grow, and describe mathematically the transition from a liquid into a glass. The theory relies on a fold bifurcation on a hyper surface. The theory does succeed in deriving several behavior characteristics of a glass transition, but, as pointed out by G. Mazenko (University of Chicago) the relevant bifurcation only arises when the coefficients of an expansion in powers of the density have precise values so a cancellation occurs. So far, no clear reason or calculation exist as why these values of the coefficients should be precisely so.

Cummins (City College, New York) described Brillouin and Raman scattering studies of the liquid-glass transition in $CaKNO_3$ and $LiCl\text{-}H_2O$ and analyzed his results in terms of mode-coupling theory. By combining Brillouin and

Raman data, Cummins was able to probe the optical spectra of these materials over five decades in frequency, and observe the evolution of the liquid spectra into the glass spectra. He found the two-step relaxation process predicted by mode-coupling theory and found that this gave a better explanation for the scattering data than the more usual phonon-induced scattering model.

Mezei (Hans-Meitner Institute, Berlin) applied high-resolution inelastic neutron scattering to investigate slow motions in spin glasses. Slow means 10^{-10} to 10^{-8} s, which is indeed slow compared to the time scale of atomic motions, 10^{-13} s. The results show characteristic features consistent with mode coupling, including the two-step relaxation process. T. Kanaka (Kyoto University) performed neutron scattering experiments on cis-1,4-polybutadiene by using spectrometers of the National Laboratory for High-Energy Physics (KEK) in Tsukuba, Japan. Universal low-energy excitations were found for these amorphous polymers that were due to tunneling between nearly identical ground states, and at higher temperatures a new mode ascribed to transitions between rotational isomeric trans and gauche states led to a second relaxation mode.

Another major theme was the description of glassy relaxations explicitly in terms of the stretched exponential relaxation function $\phi(t) = \exp[-(t/\tau)\beta]$ where β is less than one, so the relaxation is slower than the exponential. Surprisingly, this simple form, initially empirically introduced, fits an astonishing wide variety of data such as dielectric relaxation, mechanical relaxation, volumetric relaxation, NMR, and remnant magnetization. H. Suga's (Osaka University) dielectric experiments on the plastic crystals CF^2Cl and isocyanocyclohexane found the usefulness of the stretched exponential relaxation form. Although the relaxation in these systems is ascribed to the freezing of the interconversion of trans and gauche conformations, this behavior is in fact much more general. H. Scher (British Petroleum America, Cleveland) discussed how theories can account for this universal stretched exponential behavior. One popular theory relies on the notion of slow moving mobile defects that encapsulate free volume bringing this free volume to frozen-in regions of a glass and causing a relaxation to occur. This process gives exactly stretched exponential relaxation. T. Odagaki (Kyoto Institute of Technology) has used a trapping diffusion model to describe a glass transition in a supercooled fluid. As in the work described by Scher, here a distribution of jump rates is responsible for the dynamical characteristics of the system. A sharp transition (as a function of temperature) is found in the dynamical behavior, when the distribution of jump times favors longer and longer waiting times until the diffusion constant no longer becomes well defined. When this occurs, Odagaki finds that this glass transition is accompanied by strethched exponential relaxation. S. Itoh (Nishi-Tokyo University) through molecular dynamics studies investigated the motion of lithium ions in lithium iodide near its glass transition. The density-density correlations show a stretched exponential decay, and the ion motion is consistent with a trapping-diffusion transport.

Exceptions to stretched exponential relaxation do occur. Q. Tran-Cong (Kyoto Institute of Technology) studied the diffusion-controlled reaction kinetics of a molecular tracer in a miscible region of a binary polymer mixture. HNM anthracene was used as the tracer in a polystyrene and 30.polyvinylmethl ether mixture. Upon radiation with UV light the HNM anthracene undergoes photocyclization through intramolecular conformational transitions. The reaction rate are inversely proportional to the relaxation rate times of the conformational changes. The reaction kinetics did not follow the stretched exponential law, but rather they followed a combination of a fast- and a slow-relaxation law. Certain conditions are necessary to arrive at a stretched exponential law. When these conditions are met, the applicability of the stretched exponential law is remarkable, but the conditions are not always met. For example, T. Ohtsuki (Fukui University) treats diffusion-controlled recombination reactions and shows for 3-D that for the $A + B \rightarrow 0$ (with the density of A's equal to the density of B's) the densities of A and B decay as $t^{-3/4}$.

The stretched exponential relaxation law focuses on time t, but t always enters in a dimensionless manner in the form t/τ. Thus the question arises of what is the meaning of the time scale τ and how does it depend on temperature T. Some glasses, GeO_2 and SiO_2, follow the Arrhenius law $\tau = \tau_0 \exp(\Delta/kT)$, others follow the Vogel-Fulcher law of $\tau = \exp(\text{const.}/|T-T_0|)$. The mode-coupling theory predicts an algebraic fall-off of τ with $T-T_0$ raised to some high power, such as 15 for some materials. S. Kjima (University of Tsukuba) finds the Vogel-Fulcher law to give the best fit for glass-transition studies of 1,2-Propanediol and 1,2-Ethanediol. In Scher's talk, this type of increase of the time scale can be attributed to defect mediated relaxation, where the number of defects would decrease with temperature as the glass transition is approached. J. Kawamura (Hokkaido University, Sapporo) experimentally studied this

question of the T dependence of the time scale in superionic conductor glasses near their glass transition. The conductivity of these glasses can be considered as arising from mobile liquid-like ions moving in a "framework" of immobile ions. Above Tg the Vogel-Fulcher law was found to hold. Neutron scattering experiments in liquid bismuth (K. Shibata, University of Tokyo) found similar results. This law is interesting in that the time scale diverges at a finite temperature T_0. For the Arrhenius law this only occurs at absolute zero temperature. The Vogel-Fulcher law implies that something dramatic is happening at a critical temperature. This temperature is lower than the glass transition temperature that corresponds to a mechanical rigidity of the liquid-glass transition. Some theories relate the Vogel law—to the disappearance of free volume, and some to the disappearance of mobile defects that incorporate free volume.

Fukao (Kyoto University) studied dielectric relaxation in polystyrene. The relaxation is attributed to polymer chain motions and stretched exponential relaxation with a Vogel-Fulcher time-scale divergence is found. That the same universal behavior is found for this polymer liquid as for molecular liquids shows the power of theory based on scaling concepts such as divergence of a length scale. Particular details of atomic potentials will determine parameters, but the general relaxation forms are fixed from physical considerations. Other slow dynamics in chains were discussed by B. Chu (State University of NY, (SUNY) Stony Brook). He described experiments in gel electrophoresis, here pulsed electric fields separated different sized DNA chains in a gel. The DNA moves by the *reptation* process of the driven chain-end dragging the chain around structural obstacles. Longer chains get more tangled and take longer time to move a given distance. M. Shlesinger (ONR) described DeGennes' theory of how polymers *reptate* in a melt. In the original theory all the chains are frozen, but one; and the time this chain takes to move its own length is calculated and connected to the viscosity of a polymer melt. Shlesinger showed that if all the chains move, than they stay tangled up for a longer time, since some entangled chains can randomly move but in the same direction. This has the effect of giving the viscosity a stronger dependence on chain length (in agreement with experiment) than in the original *reptation* theory. M. Matsumoto (Nagoya University) also studied through simulations the movement of highly charged DNA strands in gels under the influence of a strong electric field. He finds from simulations that the *reptation* concept is valid.

SUMMARY

A major scientific effort is underway to study the physical properties of the glassy state. A major hallmark of such systems is a wide distribution of time scales for various relaxation processes. Basic ideas have been advanced that go far into explaining such behaviors as stretched exponential relaxation and Vogel-Fulcher divergence of time scales in glasses, physical and biological polymers, spin glasses, and other amorphous materials. Relaxation is the antithesis of aging, so this line of research can lead to materials that age better. The Japanese are making strong research efforts in this area, but I would characterize them as players rather than leaders in this field. However, I would not be surprised to see them push amorphous materials as novel materials for electronic applications.

Dr. Michael F. Shlesinger is Director of Physics at the Office of Naval Research. He has B.S. degrees (1970) in Mathematics and Physics from SUNY, Stony Brook, and a Ph.D. in Physics (1975) from the University of Rochester. His research has focused on stochastic processes related to the topics of fractals, chaos, turbulence, and glassy materials. His work on glasses appeared on the cover of "Physics Today" Jan. 1991 issue. He discussed random walks in a News and Views article in "Nature" Jan. 1992 issue, and he presented the 1992 Michaelson Lecture at the U.S. Naval Academy. Recently, he edited the volume *The First Experimental Chaos Conference*, which has just been published in April by the "World Scientific Publication."

FIRST INTERNATIONAL CONFERENCE ON INTELLIGENT MATERIALS, 23-25 MARCH 1992

This article reports on the First International Conference on Intelligent Materials (ICIM '92) held in Oiso, Japan in March 1992. Emphasis is on research progress in the development of polymers that behave as intelligent materials.

by Kenneth J. Wynne

The First International Conference on Intelligent Materials (ICIM '92) was held in Oiso, Japan, from 23 to 25 March 1992. This international meeting followed a series of discussions and two workshops—one Japanese and one U.S.-Japan—on Smart/ Intelligent Materials and Systems in 1990. Professor Emeritus T. Takagi of Kyoto University, who was general chairman of ICIM '92, expressed the goal of the conference very well in his introduction, "....to expand the flow of new ideas and information across the different boundaries of research" and "....to enhance the communication between (specialists) in their interdisciplinary fields of studies and help search for means to think about intelligent materials."

ICIM '92 was held at the Oiso Prince Hotel, a convenient one-hour's train ride southeast of Tokyo. The hotel, situated on a prominent hill overlooking Sagami Bay, is large and has excellent meeting facilities and spacious grounds. About 250 scientists attended this meeting. The majority of attendees were from Japan, but many other countries were represented, including the United States, Great Britain, France, Germany, Italy, Sweden, and Australia.

The sponsoring organization for ICIM '92 was the Intelligent Materials Forum [1], a subgroup of the Society of Nontraditional Technology. The meeting was supported by the Science and Technology Agency of the Japanese government and by a number of industrial advertisements in the program.

The subject matter for this meeting spanned many fields, including metallurgy, ceramics, and polymer science. The topics also encompassed drug-release materials and other aspects of biological science. The focus here is on advances in organic and polymeric materials chemistry.

Dr. Takagi, general chairman of the meeting, is currently with the Ion Engineering Research Institute Corporation, Osaka. In his opening remarks, he opined on the nature of "intelligent materials." He stated that this is a "complex materials science subject in which the material is treated to possess functional properties with the capabilities to act as a sensor, processor, and effector, and further have the feedback/feedforward abilities in the material itself."

Dr. Takagi's global view of technical progress is that we are in a transition state in proceeding from the industrial age (early 20th Century) to the information age (early 21st Century). He sees intelligent materials as playing an increasingly important role in driving this transition.

In the papers, there were many interpretations of the theme of the conference. Some scientists tried hard to set their work into the context of intelligent materials. Others totally ignored this matter and presented their work as a scientific contribution per se. This, together with private discussions, left the impression that, in varying degrees, some scientists were uncomfortable with the broad theme. The concept of intelligent materials, while intellectually appealing, is so broad that implementation as a program theme, requires incorporation of many disciplines. Thus, there were great gulfs between some of the fields of science represented. However, the program for this meeting had been put together quite thoughtfully, and when taken together, the scientific presentations provided a perspective on self-responding materials in a number of disciplines that would otherwise be difficult to obtain. As such, this information may lead to interdisciplinary activities that might not otherwise occur. Also, the knowledge of directions in one field (e.g., ceramics) may challenge researchers in other fields (e.g., polymers, metals) to take new approaches.

The broad concept of an intelligent material was interpreted by the symposium organizer in many different ways. To the biological community, the idea was reflected in work on controlled release of drugs. The objective is to build into the carrier molecules features that allow specific

delivery to and recognition by target cells. A representative paper in this category was that of Dr. M. Yokoyama (Tokyo Women's Medical College), who has developed micelle-forming polymeric carriers for drugs. In this approach, a block copolymer is constructed with hydrophobic and hydrophilic blocks (Fig. 1). The hydrophobic drug-binding block forms the hydrophobic core in the micelle, while the hydrophilic block forms a spherical sheath around this core. Figure 1 depicts the cross-section of the spherical micelle. Delivery is a function of the structure of the outer shell, which is independent of the structure of the drug-releasing inner shell. By controlling molecular design, highly effective delivery of the drug was effected against murine solid tumor C26 in mice. In contrast to a control group where all the mice died by day 49, all survived with the control-release medication.

The "intelligent" concept applied here is hierarchical. Drug efficiency was independently established—a major feat in itself. Macromolecular design was aimed at carrier efficiency and site recognition (outer core, hydrophilic block) and then the site-specific release of drug (inner-core, hydrophobic block).

A number of other papers were given addressing the intelligent materials approach to the delivery of carcinogenic drugs. In addition, papers on the delivery of other drugs (e.g., insulin), sensors (glucose) and cell attachment and differentiation were presented.

OPTICS AND ELECTRONICS

Some of the goals of intelligent materials aimed toward optical and electronic applications include the conversion of light of one wavelength to another, attenuation of light as a function of intensity, or conversion of a chemical stimulus to light or electricity. In this area, the interpretation of "intelligent materials" was reflected in the drive to obtain multifunctional materials. Often the goal was somewhat clouded, and the "smart material" looks more like a multicomponent device. Nevertheless, there were some important papers on optical and electronic materials, although there was an under-representation vis-a-vis biologically oriented papers.

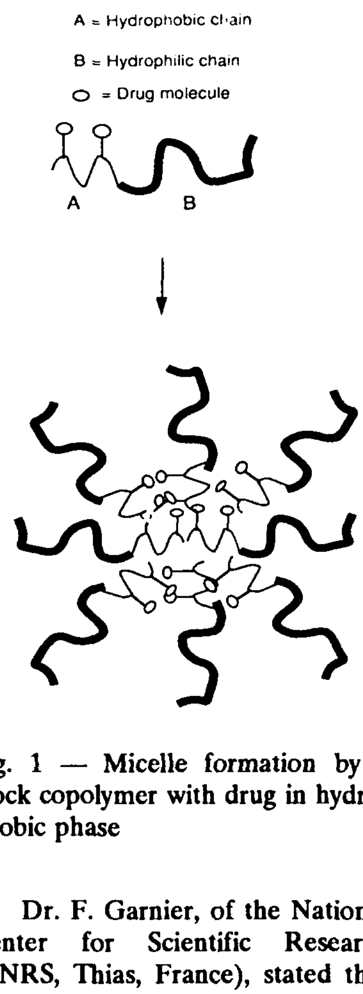

Fig. 1 — Micelle formation by a block copolymer with drug in hydrophobic phase

Dr. F. Garnier, of the National Center for Scientific Research (CNRS, Thias, France), stated that the essential feature of an intelligent material is the "ability to acquire and discriminate information from the external physical and chemical environments." He felt that intelligent materials should be patterned on the biological model and that molecular assemblies should be designed to display transduction at the molecular level. He was concerned that such assemblies be able to perform "molecular recognition toward chemical entities, ions, and optically active species, as well as toward physical quantities, (i.e.) photons or electric fields." Importantly, his concept of materials design incorporated the idea of "efficient transport of information throughout the material, toward a peripheral process unit, or between recognition centers."

The specific embodiment of these concepts in his laboratory is directed toward the properties of polymers with delocalized electronic states. By virtue of their charge-carrying capacity, these species are used as "molecular wires" in conjunction with "sensor" functionalization, as shown in Fig. 2. The depiction of a degree of polymerization of six is not accidental. The major problem that Garnier encountered was the low carrier mobility of high molecular weight electronically conducting polymers (typically about $10^{-4}cm^2/V^{-1}s^{-1}$). The low value of this parameter seriously limits current output and switching time of any device based on these materials. A careful study of mobility vs degree of polymerization (DP) revealed that a DP of 6 to 9 optimized the carrier mobility ($\sim 0.5\ cm^2/V^{-1}s^{-1}$) without sacrificing electronic conductivity. The planar structure of short chains apparently gives high carrier mobility; longer chains form a helical structure that diminishes carrier efficiency.

Sensor functionalization was carried out using novel diether, chiral diethers, metal clusters, and spiropyrans, which lead, respectively, to molecular recognition of ions, enantioselectivity, catalytic activity, and photovoltaic activity. Thus, Dr. Garnier's group showed that functionalized conjugated polymers and oligomers can be designed for operating as efficient molecular

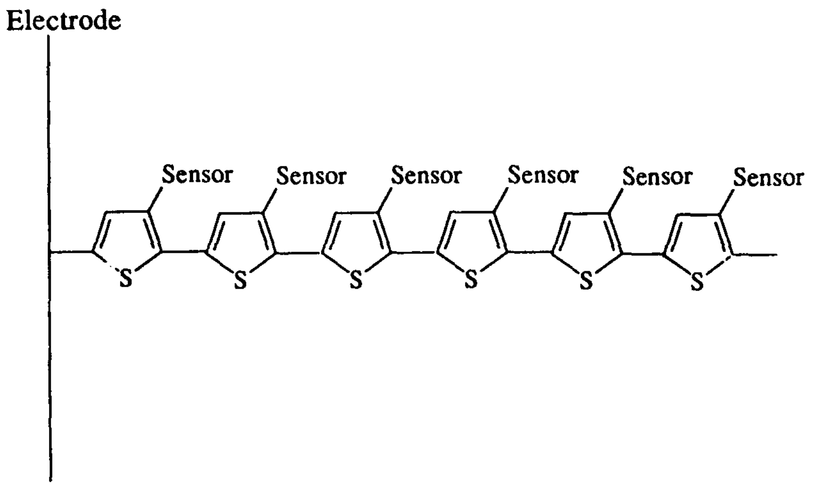

Fig. 2 — Sensor/molecular wire concept for electrochemical detection

transducers. Recognition of external physical and chemical entities was demonstrated. These results are an interesting implementation of Garnier's vision of an intelligent material.

Professor S. Miyata, Department of Material Systems Engineering, Tokyo University of Agriculture and Technology, authored an important paper on light-emitting intelligent Langmuir-Blodgett (LB) films. In this work, incoming light of one wavelength is converted to another wavelength by an absorption-emission mechanism. To achieve this result, an organic dye absorber was coupled with a lanthanide metal emitter to greatly improve emission efficiency. Lanthanide metal ions have weak absorption, but through an energy transfer process, highly absorbing organic molecules correct this deficiency. Thus LB films of the organic dye-acid behenamidobenzoic acid (BABA) and europium chloride ($EuCl_3$) were prepared. BABA absorbs strongly at 270 nm (xenon lamp), while Eu^{3+} emits efficiently at 590 and 616 nm (red). Only 10 monolayers give emission clearly visible to the naked eye. This is because fluorescence intensity of $Eu^{3}+$ in the film is 3×10^3 greater than in solution.

Another important innovation in this work was the use of a bar heater that was passed slowly across the LB film before deposition (Fig. 3). This heater converted the multidomain film into a monodomain in a zone heatinglike process. The feature was critical in eliminating scattering from small domains and resulted in a clear, emissive film.

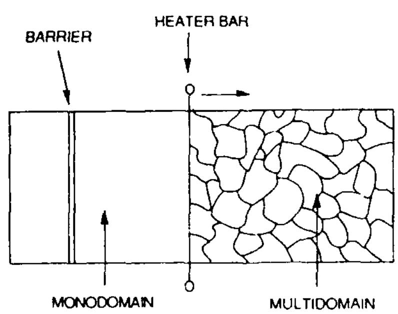

Fig. 3 — Monodomain generation in an LB trough through a zone melting like process

POLYMERGELS

Professor Y. Osada, Department of Chemistry, Ibaraki University, has been a pioneer in the development and characterization of gels that may be considered as "intelligent" materials. These gels are *chemomechanical* systems, i.e., they undergo shape changes and develop contractile forces in response to an outside stimulus.

Professor Osada presented some of his latest work on polymer gels and focussed on the effect of surfactant molecules on accentuating motility. The polymer used in this research was poly(2-acrylamido-2-methyl propane) sulfonic acid (PAMPS), seen in Fig. 4. PAMPS was prepared by radical polymerization in the presence of a 5 mol % crosslinking agent [2].

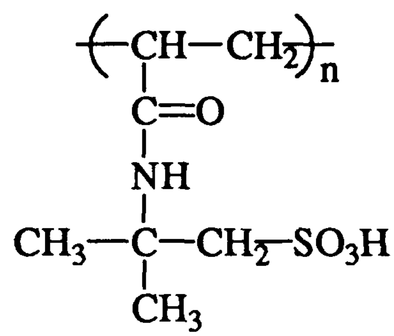

Fig. 4 — Structure of poly(2-acryl amido-2methyl propane) sulfonic acid (PAMPS)

An interesting experiment was devised to demonstrate the electrochemically driven compositional changes in the gel that occur in the presence of electrolyte and surfactant (Fig. 5). A strip of the PAMPS gel was prepared, and a pair of plastic hooks that act as pawls were attached to the ends. The strip was suspended from a plastic ratchet bar and then immersed in a dilute solution of a surfactant and salt. The gel swells by a factor of 45 in this solution when compared with its dry weight.

A dc voltage was applied through a pair of planar carbon electrodes placed above and below the top of the ratchet bar. The nominal

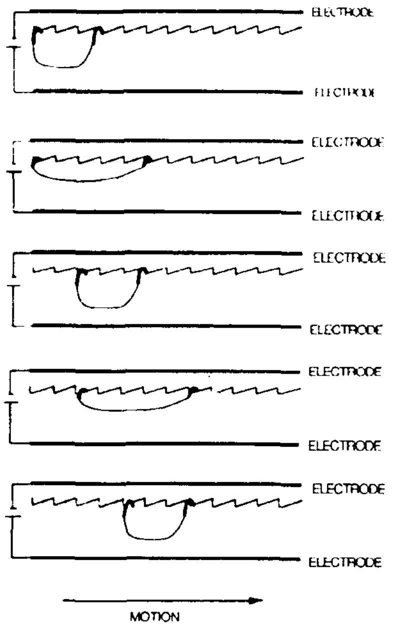

Fig. 5 — The "gel-looper" experiment of Osada showing how, with the aid of a ratchet and hooks, the expansion and contraction of the polymer gel strip is converted to linear motion

field was 10 V with a current 15 mA cm^{-2}, and the polarity was changed at 2-s intervals. The interesting result was that the gel strip moved along the bar, alternately expanding and contracting as the field reversed. A study of salt and surfactant concentrations revealed optimum concentrations for maximum motility.

Professor Osada's explanation for the phenomenon is as follows. "When the voltage is turned on, positively charged surfactant molecules move by electrophoresis toward the cathode and form a complex with the negatively charged gel, preferentially on the side of the PAMPS strip facing the anode. This causes anisotropic contraction, bending the gel toward the anode. When the polarity of the field is changed, the surfactant molecules are released from the gel and electrophoretically travel toward the anode, while new surfactant molecules form a complex on the other side of the gel and cause a straightening." Professor Osada noted that the changes in the shape of the gel are due to its cross-linked nature, whereby molecular motions are communicated to the macroscopic structure. Thus this effect is different from shape-memory materials, where shape change is caused by a phase transition.

Professor Osada showed a video tape of the "gel-looper," which "walked" at a velocity of 25 cm min^{-1}. All present were fascinated by the gentle, musclelike action that was mimicked.

Dr. H. Ichijo, Research Institute for Polymers and Textiles, Tsukuba, reported work on the thermally induced phase transitions in polymer gels. His work began with the observation that linear, atactic poly(vinyl methylether) (PMVE) in water displays a solubility-insolubility transition at 38°C. The incorporation of such a polymer into a gel produces a material that undergoes marked volume changes at the transition temperature. In addition to temperature, such gels are sensitive to salt concentration and acidity. Tanaka has shown that the ratio of swollen volume to contracted volume can be as high as 1000 [3].

In Dr. Ichijo's work, atactic PVME was synthesized at ambient temperature by cationic initiation. The polymer is dissolved in water below the temperature of insolubility and is crosslinked by gamma ray irradiation. The resultant gel swells (<38°) and shrinks (>38°) reversibly in water.

The process of swelling and shrinking is relatively slow for a monolithic piece of gel, as solvent molecules must traverse long distances by diffusion. To improve the kinetics of the swelling process, Dr. Ichijo increased the surface area in a number of ways. In one approach, a polymer blend of PMMA with sodium alginate was prepared and spun into fibers that were crosslinked with gamma radiation. These gel fibers have a spongelike morphology that leads to rapid swelling and shrinking in response to temperature changes. In a typical experiment, fiber diameter changes from 400 μ (20°C) to 200 μ (40°C) in <1 s.

Dr. Ichijo expects applications for gels where an external stimulus causes changes in chemical properties, such as hydrophilicity and hydrophobicity, physical properties such as dimension, strength, and elasticity, and optical properties such as opacity and transparency. An illustration of potential applications is found in the modulation of activity of enzymes. In this case, amylo-1,6 glucosidase from A. niger and PVME are irradiated in aqueous solution to produce agel. The activity of the enzyme trapped in the gel drastically decreases near the phase transition point of PVME. Apparently the exclusion of solvent above the polymer collapse temperature prevents glucose from permeating through the membrane. Lowering the temperature rehydrates the gel and re-initiates enzymatic activity.

Other approaches to achieving rapid response from polymer gels included the work of Professor M. Aizawa of the Tokyo Institute of Technology and Dr. T. Sawai of the Asahi Chemical Industry, Tokyo. They achieved an aqueous dispersion of "microgel" particles of poly(co-methyl methacrylate-acrylic acid) (MMA-AA) in the presence of poly-(L-lysine) (PLL). At pH's above 10, the MMA-AA was dispersed, but at lower pH's, the PLL bridged the microgel particles and caused phase separation (flocculation). The reversible phase change occurred in a

few seconds and was monitored optically.

CONCLUSIONS

Outlined are a few of the contributions that concerned polymers as "intelligent" materials. As noted in the introduction, the contributions to this meeting addressed many other areas, including shape memory alloys, electrorheological fluids, magnetostrictive materials, solid-state inorganic materials, and biological systems for cell differentiation, drug release, cell-targeting, and molecular recognition. This is the kind of meeting where it is useful to take advantage of cross-fertilization of fields. Thus, Professor Takagi and the Intelligent Materials Forum achieved their goals of a broadly based meeting centered on materials that change their properties in response to an outside stimulus.

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ELECTRONIC MATERIALS RESEARCH IN THE PEOPLES REPUBLIC OF CHINA

In this report I review the progress of several research institutions and laboratories in electronics-related research and synchrotron-radiation-based research in the People's Republic of China, as I observed it during the period 7 to 21 May 1992. In visiting only three cities (Beijing, Hefei, and Shanghai,) my observations are far from comprehensive in any terms. However, the institutions and laboratories I visited are reputed to be among the best, if not the best in China, and should represent well the general status of surface, semiconductor, and synchrotron-based research in China in 1992.

Victor Rehn

INTRODUCTION

China is the great sleeping giant of Asia, with nearly 1.2 billion people on a land mass slightly smaller than the United States, and great stores of undeveloped natural and human resources. In recent history, Chinese scientific progress suffered enormously from the ten-year rule of the "Gang of Four," who bestowed upon the people of China the infamous "Cultural Revolution."

During those dark days of the Cultural Revolution (1966 to 1976), universities and research institutes were either closed or converted into virtual factories. Many educated persons, especially artists, entertainers, and writers, were persecuted, imprisoned, or sent to work in agricultural collective farms or in *approved* industry. Those few who were permitted to remain in their research or educational institutions were directed to produce practical products for the people, a category that excluded advanced education. Metallurgy departments were directed to produce steel, for example, and electrical engineering departments were directed to produce electrical or electronic devices and to train workers to work in factories.

The effects of the Cultural Revolution are still felt strongly among the scientists and engineers, as well as among artists, religious leaders, and scholars of China. In the physics departments of universities and research institutes, most current leaders are scientists trained (largely overseas) prior to 1966. They are supported by young scientists trained in the 1980s, but there is an absent generation. Midcareer Ph.D. level scientists, who should have been trained in the 1970s, are very scarce in China. In their place are scientists with less academic training, who work to fill the void.

In the early 1980s China began a program to upgrade the staff and scientific equipment of its research laboratories. They sent many students overseas for advanced training and Ph.D. degrees. They also authorized the purchase of major scientific apparatus from foreign sources (Europe, the United States, and Japan). In the major research institutes now, researchers are using some of the finest scientific apparatus available in Europe or the United States in the early 1980s. Little newer scientific equipment apparatus from overseas is apparent, but the quality and variety of Chinese-built scientific equipment has improved noticeably over the six years since my last visit. However, that is not to suggest that China is approaching self-sufficiency in scientific equipment, but only that significant contributions to laboratory equipment is now available from Chinese sources.

RESEARCH IN CHINA: WHO DOES IT AND WHO PAYS FOR IT?

Research in China is highly diversified among universities, research institutes, and industrial institutions. Each of the major ministries of government operates a network of research institutes whose efforts support both the long-range and short-range goals of the ministry. Chief among the ministries involved in research related to solid state physics are the Ministry of Education, the Chinese Academy of Sciences, the

Ministry of Machinery and Electronic Industry, and the Chinese Academy of Space Technology. In addition, both provincial and major city governments may operate or fund research institutes.

As with any large country, research funding in China is provided by several agencies of government. Most funding for university research comes from the Ministry of Education. The Chinese Academy of Sciences (variously referred to as CAS, CAST, or Academia Sinica) operates more than 100 research institutes throughout the country. Although the institutes tend to be small by American standards (several hundred persons), they are prestigious and generally are productive research institutes with broad-scale of research and development activities.

Over the past few years, funding of research institutes has changed from total to partial institutional support. There are both positive and negative implications in this change. On the one hand, the level of institutional support from CAS has decreased considerably, relative to the total operating costs. On the other hand, opportunities are offered to seek either focussed-program support or support from collaborating industries. Funding opportunities in focussed national research and development programs may be in basic research areas, such as the State Key Laboratory program, or in development/application areas where major national needs are identified, and researchers are invited to compete for involvement.

As a consequence, five-year-plan goals are being approached through a competitive process as opposed to assignment as part of the mission of certain research units, as it were in the past. Although institutional support is sufficient to pay, survival costs are still distributed to research institutes by CAS, funds for research equipment and other operations must be sought by the institute leadership.

At the time of my visit, about 12 areas of science had been identified for special funding from the Chinese National Science Fund. One of these is the development of superlattices and microstructures. Other priority subjects will be announced in the future, perhaps 30 in all. Funding for these priority subjects will consume about 10% of the total Chinese National Science Fund, I was told.

In addition, a separate budget exists for development of national critical technologies. These budgets are organized by separate ministries outside the purview of CAS. Also, the Commission of Science and Technology has a high-technology fund for larger projects that involve expert groups.

Priority research laboratories are being established. About 70 national centers for priority research have already been established, and 70 centers have been planned. (Hefei National Synchrotron-Radiation Research Laboratory is one of these national centers for priority research.) Most of these laboratories are not freestanding, independent research institutes, but rather are laboratories within existing research institutes, such as the Laboratory for Superlattices and Microstructures of the Institute of Semiconductors.

HIGHER EDUCATION

Higher education in China is provided through a hierarchy of universities, research institutes, and other institutions. The Ministry of Education funds most of the national universities, including the prestigious Peking and Tsinghua universities in Beijing and the Fudan University in Shanghai. The Academia Sinica (Chinese Academy of Sciences) is the main provider of research facilities outside the universities, but operates only one university, the University of Science and Technology of China (USTC) in Hefei, Anhui Province.

Through its more than 100 research institutes scattered in various parts of China, Academia Sinica offers a considerable resource for research and for advanced education and training in the sciences. Most, if not all, of the institutes of Academia Sinica have a dual role of research and education, offering B.S., M.S., and some Ph.D. programs for employee-students. Although not so prestigious as a degree from a national university, an advanced degree from many of the Academia Sinica institutes involves working with advisors who are well-trained Ph.D. scientists of international fame.

For example, the Institute of Semiconductors in Beijing has an active education program. The Institute awards doctor degrees both in natural science and in engineering. Since 1978, the Institute has been taking in an increasing number of graduate students. Up to 1992, 42 master degrees and 5 doctor degrees have been awarded. At the present, 78 graduate students are at the Institute of Semiconductors, and 15 students are doing postgraduate studies at universities abroad.

All the national universities and research institutes are small by U.S. standards. The largest national universities have less than 15,000 students, and the majority of these are undergraduates. Typical research institutes of Academia Sinica have from a few dozens to a few hundred employee-students, mostly graduate

students, and mostly, if not all, majoring in science or engineering disciplines, which is consistent with the mission of the Institute.

In addition, there are research institutes associated with other ministries, such as the 50 research institutes of the Ministry of Machinery and Electronic Industry. From the educational perspective, they operate similarly to institutes of Academia Sinica but often maintain a more near term engineering orientation, including either in-house production facilities or close cooperation with production facilities. Among the institutes of the Ministry of Machinery and Electronic Industry is the Beijing Vacuum Electronics Research Institute (BVERI), which is reviewed below.

Many additional educational institutions are administered by provincial and city governments. For example, in Hefei, home of USTC, 19 other universities and colleges are sponsored by Anhui Province. Some of these universities are large, up to 100,000 students. Most teachers and many engineers are trained in these institutions.

Medical education, for example, is not obtained from national universities. Instead, medical education is obtained from special medical schools operated by provincial or city governments. No regular university education is required for entry, and instruction of medical personnel in the sciences is the responsibility of the medical school instruction staff. People with only four years of education beyond secondary school are graduated and employed in hospitals and clinics as full medical-staff members.

Fully trained physicians with training obtained overseas are rare in Chinese medical facilities, where traditional Chinese folk medical practices are still respected and practiced in major hospitals as well as in local medical clinics. Although medical service is free or nearly free for Chinese citizens, medical service for western tourists may cost whatever price seems reasonable to the provider. It may be as little as the cost of the X-ray film for an X ray, or as much as the provider's impression of what it would cost the tourist in his homeland.

PEKING UNIVERSITY, BEIJING

Two of China's most prestigious universities are located adjacent to each other in northwest Beijing: Peking University (which never changed its name from the old British name to the modern Chinese name of the capitol city) and Tsinghua University, which is discussed below.

The Institute of Microelectronics is hosted in the University by the Department of Computer Science and Technology in close cooperation with the Department of Physics. One of the main teaching facilities is the prototype production facility for semiconductor electronics (silicon technology). This facility is housed in a class 1000 clean area and includes facilities for handling two-inch or three-inch wafers. Although simple masks can be produced on site, more complex designs are sent to a mask shop in Shanghai, with a turn-around time of about one week. Mask designs are produced by students or researchers on PC-type computers or workstations, and they may be tested by building prototype ICs for in-house testing.

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TSINGHUA UNIVERSITY, BEIJING

Institute of Microelectronics at Tsinghua consists of 10 professors, 35 associate professors, 25 lecturers, and other assistants, technicians, and secretaries for a total of 137 persons. The student body consists of 183 undergraduate students, 27 M.S. students (10 per year are accepted), 18 Ph.D. candidates (5 per year are accepted), and one postdoctorate (from another university, on a two-year limited appointment). Over the past three calendar years, they have awarded eleven Ph.D. degrees, and 38 M.S. degrees.

As at the Peking University, Tsinghua University also has a 3 to 4μm prototype semiconductor-production facility for teaching use. However, in 1989 Tsinghua installed a 1μm prototype production facility as well, which is reserved for faculty research and collaborative developments with industries and other laboratories.

Within the Institute of Microelectronics, the research programs are divided among five divisions:

Device Physics Research Division

This Division is headed by Professor Liu Litian, has programs in very-large-scale integration (VLSI) technology, advanced integrated sensor techniques, fuzzy logic and multiple-valued logic, optoelectronic integration, (which includes the quantum-well GaAs/Si laser), and hot carrier effects in submicron metal-oxide-semiconductor field-effect transistor (MOSFET).

IC Design-Research Division

This Division is headed by Professor Yue Zhenwu, has programs directed toward development of a 1 Mbit Chinese-character ROM, the first ULSI in China, with more than a million transistors. Other programs include the architecture analysis of the RISC SPARC 32-bit CPU, an asynchronous communications interface 8250 and direct-memory access (DMA) controller 8237; the 8086/8088 CPU have been put into production by Shanghai Bellin Company. A research-level programmable transistor neural network suitable for integrated circuit use is under study, and a buried twin-well epitaxial structure bi-complementary metal oxide semiconductor (bi-CMOS) technology has been improved.

IC Technology Research Division

This Division, headed by Professor Li Ruwei, conducts research programs in VLSI process development and optimization, submicron VLSI technology research, short-channel device physics, process control monitoring, and CAM system development. Their fabrication line is producing 1 to 2μ normal metal oxide semiconductor (NMOS) and CMOS wafers, 3-in. diameter (soon to be increased to 4-in. size) as a small foundry for outside collaborators and customers, as well as for internal research programs. The facility includes 100 m^2 of class 10 clean space and 600 m^2 of class 1000 clean space in which a complete processing facility is located.

Research and Development Division of Microelectronic Technique

This Division is headed by Professor Zhang Jian-ren. It emphasizes development of application-specific integrated circuits (ASIC) and chip-packaging development. Recent ASICs included tow for communications and the 1 Mb ROM referred to above.

IC CAE Research Division

This Division is headed by Professor Gu Zuyi. It works on research programs in software development for CAM of ICs, design of dual-metal-layer CMOS gate arrays, CMOS gate arrays with 10,000 equivalent gates, amorphous Si-hydrogen thin-film transistors, capacitance-voltage testing instrumentation, and statistical optimum design of VLSICs.

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UNIVERSITY OF SCIENCE AND TECHNOLOGY OF CHINA (USTC), HEFEI, ANHUI

As the only university of China established by the Academia Sinica (1958), USTC was moved from Beijing to Hefei in 1970. Currently under the leadership of President Gu Chaohao, its student body numbers about 5,000, of whom about 800 are M.S. students and 200 are Ph.D. students. They are recruited from many parts of China to study in an academically democratic atmosphere. The University offers special classes for the gifted young and boasts students as young as eleven years of age. The average age of new students is only 17 years. The University has two campuses not far apart in Hefei, which is a small city of 800,000 inhabitants and the historical provincial capital of Anhui Province. In addition, there is a USTC graduate school in Beijing.

USTC warmly welcomes and strongly encourages international academic collaborations and exchanges. During my short visit, I met visiting scholars from Japan and from Australia. USTC currently lists 14 foreign institutions with whom they have currently active agreements. Eight of these are U.S. institutions. They also list 31 foreign honorary professors, of whom 21 are U.S. citizens.

Among the 21 departments, centers, divisions, and laboratories of the university, the largest department is the mathematics department. There are three physics departments, an earth and space sciences department, a computer science and technology department, two chemistry departments, and the Hefei National Synchrotron-Radiation Laboratory (HESYRL).

The three departments of physics are differentiated according to their specialization. The department of physics specializes in semiconductor physics, superlattices, quantum confinement effects, solid-state and low-temperature physics, and high-temperature superconductivity. The department of modern physics specializes in particle physics, gravita-

tion, plasma physics, nuclear physics and technology, and atomic physics. The center for fundamental physics specializes in cosmology, relativistic astrophysics, quantum field theory, metal-semiconductor interface physics, solid-state applications of the Mossbauer effect, and microanalysis.

Some of the laboratory facilities I saw were:

- A Vacuum-Generators XPS-LEED-AES-profiling system on which studies of coadsorption Cl or CO and oxygen on Ni(100) or Co-Ni-(100), and its effect on oxidation, were being studied.
- A SPEX Raman spectrometer with Spectra-Physics Ar+ laser being used for studies of (Al,Ga)As epilayer growths on GaAs to measure and characterize the film quality.
- A Nicholet FTIR apparatus being used for studying the structure of polymers.
- TEM-STEM-EDAX-energy-dispersive X-ray spectrometer being used for the study of polycrystalline diamond thin films on Si substrates.
- Three-target magnetron-sputtering systems for producing Mo films on Si, or yttrium-based high-temperature superconductor thin films.

Other apparatus discussed with me included a molecular-beam epitaxi (MBE) system devoted to growth of AlGaAs epilayers on GaAs, and CVD systems devoted to deposition of thin-film diamond films on Si, as well as Mo-Si multilayer mirrors for application in soft X-ray synchrotron radiation. In the latter case I saw a small mirror comprising 50 layer pairs with a peak reflectivity at a wavelength of 6 nm. In X-ray diffraction using a graphite crystal, angular resolution of 0.01° has been achieved.

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Hefei Synchrotron-Radiation Research Laboratory (HESYRL)

This laboratory is located in the smaller, newer west campus of USTC. The synchrotron radiation is provided by a dedicated 800 MeV storage ring that is injected from a 200 MeV linear electron accelerator. The storage ring is housed in a modern, circular-domed building with ample space for beamlines and experimental equipment. After seven years in construction and commissioning, HESYRL became fully operational in 1992. Storage of up to 327 mA of beam current has already been achieved, thus exceeding the design goal of 300 mA.

At present, there are five beam lines, operational or nearly operational on the storage ring, all from bending-magnet source points. Future expansion will allow up to 24 bending-magnet beam lines and three insertion-device beam lines.

Currently, the five beam lines are used as follows:

Beam line U_1 uses a white-beam station devoted to submicron lithography, surface sonic-wave device fabrication, and millimeter/microwave device lithography.

Beam line U_{10A} uses a 1-m Seya-Namioka monochromator to provide vacuum-ultraviolet radiation for the study of free surfaces and interfaces of semiconductors and crystals, as

well as surfaces of noncrystals and organic semiconducting materials.

Beam line U_{10B} also uses a 1-m Seya-Namioka monochromator to provide vacuum-ultraviolet radiation for active biological and medical research in the processes of growth, aging, and cancerous mutation.

Beam line U_{12A} uses a zone plate monochromator for the study of fluorescence lifetimes in noncrystals and in laser materials, as well as for low-temperature fluorescence-lifetime research on proteins and energy transitions in rare earth materials. This unusual monochromator is tunable in the wavelength range 2 to 5.4 nm, and achieves a resolving power of 200. However, the acceptance angle is severely limited, and the flux throughput is low. X-ray images magnified up to 1850x are routinely obtained.

Beam line U_{20A} uses a copy of the famous Dragon monochromator at the National Synchrotron Light Source, Brookhaven, NY. This state-of-the-art instrument will use four diffraction gratings to provide radiation over the wavelength range 1.2 to 120 nm with a resolving power of 1000, and medium flux throughput. However, the four holographic, SiC gratings are two years overdue from the English supplier. Hence, two temporary gratings have been made locally so that some preliminary experiments may be started, albeit with much lower resolving power.

Research on the U_{20A} beamline will be devoted to atomic and molecular absorption spectroscopy, photoionization spectroscopy, chemical reactions between molecules with highly excited orbital electrons, and molecule-ion reactions.

Although nanosecond time-resolved experiments are planned, single-bunch running of the storage ring, as needed for these experiments, has not yet been achieved.

HESYRL is a national research institute that is open to and shared by researchers from all over China. Users from abroad are welcome, and interests in building user-owned beamlines or experiment stations will be favorably considered.

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FUDAN UNIVERSITY, SHANGHAI

The Surface Physics Laboratory of Fudan University that shares the title of "State Key Laboratory" with the Laboratory for Surface Physics Institute of the Academia Sinica in Beijing, was founded by Professor Xie Xide, who is now partially retired, but still leads the theoretical group. Ms. Xie is one of the most prominent solid-state physicists in China, and is well known worldwide. Currently the Surface Physics Laboratory is ably lead by WANG Xun, an experimentalist with a strong interest in epitaxial growth of semiconductors.

Three major thrust areas are identified at the Surface Physics Laboratory:

- Silicon MBE, heterostructures, superlattices, and silicon band-gap engineering.
- Surfaces and interfaces of III-V semiconductors.
- Development of new surface analytical methods.

These three thrust areas are coordinated with three experimental groups: the MBE Group headed by Wang Xun, the Photoemission Group headed by Chen Ping, and the New Surface Technique Group headed by Zhu Angru.

The laboratory is well equipped. Among the major systems for experimental research are

- — Vacuum generators ADES 400 two-chamber angle-resolved electron spectrometer.
- — Vacuum-Generators Escalab-5 multifunction electron spectrometer.
- — Riber Model SSC electron-beam evaporator.
- — LEED-AES system with Arion sputter profiling capability.
- — Another LEED-AES system with inverse photoemission and total current spectrometer capabilities.
- — Photoacoustic spectrometer with CO2 and HeNe lasers, and ZnSe vacuum window.
- — Scanning tunnelling microscope in ambient air.
- — Hot-wall epitaxial deposition system.

These major instruments support a very active research program in surface physics.

Professor Wang Xun has a strong interest in Si-Ge superlattices. There are two Riber MBE systems and two older domestic MBEs for sample preparation. RHEED-oscillation control is used in the epitaxial

growth of Si-Ge superlattices that include thin, two-cycle growths. However, photoluminescence (PL) characterization is currently not available in China for Si-Ge superlattices. Wang plans to establish a new PL capability that will be installed on an existing Raman system, to search for the elusive free exciton in Si-Ge superlattices. Much of the characterization of samples grown in Wang's laboratory is done at the Peking University, or elsewhere in China.

The Surface Physics Laboratory conducts device research oriented toward infrared detectors and heterojunction bipolar transistors. However, at present the Surface Physics Laboratory has no capability for processing epitaxially prepared wafers into useful devices.

In the Applied Surface Physics Laboratory, studies of passivation of III-V semiconductor surfaces through electrochemical processes are underway. Thick sulphur layers are prepared, as opposed to the submonolayer sulphur passivation interlayer reported by NTT in Japan. Wang's experience indicates that the submonolayer sulphur interlayer is not sufficiently stable.

Porous silicon is an active research topic in the Applied Surface Physics Laboratory, as well. Electroluminescence has been observed, along with nonlinear optical properties. Quantum confinement may play a role in the electroluminescence, and a three-photon process is being considered as a possible mechanism for the nonlinear optical behavior. The third-order susceptibility coefficient ≈(3) has been measured, and infrared up-conversion has been observed.

The theoretical group headed by Professors Xie Xide and Zhang Kaiming have been interested in lattice dynamical calculations. Applications to b-SiC(111) have been reported recently. It has been predicted that Fermi-surface pinning at a Au-coated surface will be caused on the Si-terminated surface by an intrinsic surface state in the gap. On the C-terminated surface, however, that surface state lies near the top of the valence band. Adsorption of Al on the b-SiC(100) surface shows quite different properties. Al adsorption hardly affects the Si-C bond in the Si-terminated (100) surfaces, while appreciably weakening the Si-C bond on C-terminated (100) surfaces.

In recent studies of strained Si, Ge, Si/GaAs and Ge/GaAs interface systems.

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Microelectronics Institute of Fudan University is ably and energetically directed by Professor Ruan Gang of the Electrical Engineering Department. Research at the Institute is directed mainly toward the study of silicides of Ta and Co, solid-state interactions in $CoSi_2$, silicide layers on Si-Ge materials, and porous silicon for SOI applications. The Institute collaborates closely with neighboring industries. With 14 million people, Shanghai is the major industrial center of China, and probably the second major cultural and educational center after Beijing.

Prototype devices are made with 4μm line widths. Processing techniques used include mask aligning, sputter etching, plasma etching optical lithography, diffusion and annealing furnaces for 2- and 3-in. Si wafers, and ion implantation for P or Al (200 KeV). Mask designs are recorded on magnetic tape and sent to the Shanghai Mask Center. One large deposition system includes three different sputter-deposition techniques, a) electron-beam sputtering, b) ion-beam sputtering, or c) radio frequency plasma discharge sputtering from any of six different targets.

In characterization their facilities are weak. They rely on scanning electron microscopy (SEM), transmission electron microscopy (TEM), and Raman spectroscopy, however they have no photoluminescence (PL).

The emphasis on $CoSi_2$ is in recognition of the close lattice match with Si (about 2% mismatch), which makes epitaxial contacts conceivable. It is generally agreed that epitaxial contacts will show better stability, lower contact resistance, and lower contact noise (1/f noise) than alloyed contacts. Results of recent research on $CoSi_2$/Si contact formation at the Fudan University has shown that epitaxial contacts may be realized through solid-state reaction of thin bilayers ($\approx$ 10 nm) of Co/Ti on either (100) or (111) Si substrates.

Bilayers of Co/Ti were deposited by ion-beam sputtering, and thermally annealed in a multistep process by using a halogen lamp in a nitrogen ambient. Results show that the Ti is displaced to the surface, and an epitaxial $CoSi_2$ contact layer is formed. TEM cross-sectional micrographs show a very sharp and uniform $CoSi_2$/Si interface.

Theoretical work at the Institute is directed by Prof. Tang Ting-ao. Considerable effort is directed toward modelling devices that include new and proposed devices using Si-Ge materials.

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INSTITUTE OF SEMICONDUCTORS, ACADEMIA SINICA, BEIJING

Historical Background

The Institute of Semiconductors is a multidisciplinary semiconductor research institute belonging to the Chinese Academy of Sciences. The Institute was established in 1960. The semiconductor division was the basis of the Institute of Physics, Chinese Academy of Sciences. At its inception, five research divisions were established that worked respectively on materials, devices, measurements and characterization, electronics and optoelectronics. The other three research groups worked in physics, chemical analysis, and thermoelectricity. Later, they were reorganized into seven research divisions and a pilot plant, the "109 plant," for fabrication of planar Si transistors.

In 1964, a part of the optoelectronics division was transferred to the East China Research Institute of Technical Physics (now renamed "Shanghai Research Institute of Technical Physics") and the 109 plant became an independent plant under the Academy of Sciences. In the same year, work on integrated circuits began, and later the plant became organized into two research divisions that respectively worked on bipolar and MOS circuits. Very recently, a "Center of Microelectronics" has been created within the academy, based on the VLSI team of this institute and the 109 plant.

The institute is located in the Haidian District of Beijing; it neighbors Tsinghua University to the west and the Beijing College of Forestry to the south. The institute occupies an area of about 87,000 m^2 (about 22 acres). The main laboratory buildings include a seven-story material-and-device laboratory building, and a five-story physics-chemistry-electronics building, surrounded by the ion-beam laboratory, the clean room, the computer center, the library, and the general office building. The total laboratory floor space is about 30,000 m^2. The institute also provides living quarters.

The institute has made important contributions to the national development of semiconductor science and technology, and has undertaken many priority national projects. The Institute has also received many national and CAS awards for achievement.

The honorary director and senior advisor of the institute is Professor Huang Kun, who spent 28 years as professor at the Peking University and about eight years as Director of the Institute of Semiconductors. He is one of four division members of the Chinese Academy of Sciences at the institute and continues an active role in science internationally, as well as in the research at the institute. The current director of the institute is Professor Wang Qiming.

Organization of the Institute

At the present time, the total number of personnel at the institute is about 1,000. The number of scientists and engineers with senior status is more than 100, and scientific personnel with intermediate and junior status is about 500. In recent years, the total number of scientists who have been abroad for a period of time for further studies or to carry out cooperative projects is above 60.

Project groups form the basic units for carrying out scientific research, technological experiments, or developmental projects. The work of a project group is usually subdivided into a number of research tasks to be carried out. The project groups are organized into one division and nine laboratories as listed:

- — Division of Semiconductor Physics
- — Laboratory of Semiconducting Materials
- — Laboratory of New Devices
- — Laboratory of Ultrathin Film Growth
- — Laboratory of Sensors and Surface Devices
- — Laboratory of Microwave Devices
- — Laboratory of Applied Electronics
- — Laboratory of Optoelectronic Devices
- — Laboratory of Physical and Chemical Analysis
- — Laboratory for General Processing.

In addition, the institute has an experimental device-processing factory and a number of supporting facilities, such as library, machine shop,

and computer center. The editorial office also belongs to the institute. One of their major jobs is to edit the "Chinese Journal of Semiconductors," the major national journal on semiconductor science.

Research Areas

The following four research areas are currently active at the institute,

1. Semiconductor theory and basic physics

This area includes the following six main topics:

Solid-state theory, including lattice relaxation, multiphonon transitions, and theoretical calculation of various electronic structures. A theoretical multifrequency model has been developed to implement multiphonon transition calculations, and a statistical-distribution law has been established for the phonons emitted in multiphonon transitions. Electronic structure calculations have included development of theoretical methods as well as a wide range of applications, such as bulk band structures, deep centers, semiconductor surface, amorphous silicon, quantum wells, and superlattices.

Physics of amorphous semiconductors presently focusing on the long-term stability of amorphous silicon under illumination, and the optoelectronic energy-conversion efficiency. On the basis of physical research, small area solar cells of amorphous silicon with a conversion efficiency of 9 % have been made.

Physics of low-dimensional systems, a relatively new field of investigation at this institute. Research on the properties of a 2-D electron gas in metal oxide-semiconductor (MOS) structures and on modulation-doped heterojunctions was first started in 1981. Research work has included optical investigations and electronic transport at low temperature and high magnetic fields.

Semiconductor surface physics. Surface and interface investigations with electron spectroscopy have been conducted on a number of topics, such as oxygen absorption and desorption on GaAs and Si surfaces, compositional effects at interfaces, the effects of defects and impurities on Schottky junctions, and problems relating to interfaces between a semiconductor and an oxide or nitride film.

Semiconductor spectroscopic research has been directed toward a wide range of scientific questions. Examples are photoluminescence under high pressure as a means of studying nitrogen-bound excitons in GaP or GaAs, or excitons in quantum wells. Raman spectra of disordered systems (mixed crystals and amorphous materials), and picosecond-spectroscopic investigation of the transient behavior of hot carriers in quantum wells. Physical problems closely related to junction lasers are investigated; for example, carrier losses and Auger processes in (In,Ga)(As,P) / InP double heterojunction lasers.

Deep-level centers. Systematic investigations on the properties and behavior "4d impurities" in Si are carried out with various junction-capacitance techniques. Also, nonmetallic elements (oxygen and carbon) in silicon are being investigated, mainly in relation to their thermal-annealing behavior.

2. Semiconducting materials and related material physics

Earlier, materials research at the Institute had focussed on the growth of perfect silicon single crystals. With the development of large-scale integration (LSI), technology in China, proper technology for the growth of silicon crystals with low-dislocation density, no swirl defect, and with uniform resistivity has been developed at the Institute. At present, work on silicon is mainly done on the investigation of micro defects and the so-called new donors, and on thermal annealing behavior.

Currently, growth of semi-insulating GaAs and InP is also a priority subject for research. In the crystal pulling laboratory there are high-pressure vessels that contain up to 100 atm overpressure of phosphorous for pulling InP, GaAs, or GaSb. Two-in. diameter InP crystals more than 4-in. long are routinely pulled with n, p, or intrinsic doping. The background impurity levels are as low as 5×10^{15} cm^{-3}. (Five laboratories in China currently produce InP substrate material.)

With the addition of Ga to the InP, the etch-pit count can be reduced from 5×10^4 to $1 - 5 \times 10^3$-cm^{-2}. Their current problem with both GaAs and InP substrate materials is learning to polish it satisfactorily for the demanding application in multiple quantum-well epitaxy, a problem that has been solved with GaSb.

Single crystals of GaSb, 3-in. in diameter, are pulled routinely and are available for international sale.

GaAs single crystals of 4-in. diameter are pulled, doped n, p, or intrinsic. The intrinsic GaAs is undoped and has a resistivity of 5×10^7 Ω-cm.

Epitaxial growth has always been one of the main topics of research in materials preparation. Work on silicon is directed toward developing new methods for low-temperature growth of high-quality epilayers. Heteroepitaxial growth is being pursued with silicon-on-sapphire (SOS) materials, related to the development

of sensors and radiation-resistant ICs. Completely new modes of epitaxial growth are also being explored.

Ultrathin-film growth is considered to be of great importance. The earliest effort of the Institute dates back to 1976, when the decision was made to design an MBE apparatus to be built in China. For several years up to now, good quality modulation-doped heterojunctions and superlattices have been grown. Efforts are being made to initiate research at an early date on metal-organic chemical-vapor deposition (MOCVD) growth. In the past few years, experimental research on MBE-grown quantum wells and superlattices has increased rapidly. Related device research has now begun.

3. Device research and device-physics research

Device research at this institute includes optoelectronic devices, microwave devices, special integrated circuits (IC) and various sensors. This institute was among the earliest to start work on semiconductor epitaxial layers.

In recent years, extensive work has been done on the development of long-lifetime (Al,Ga)As/GaAs double-heterojunction lasers, low-threshold (In,Ga)(As,P)/InP long-wave length double-heterojunction laser, (Al,Ga)As/GaAs double-heterojunction power lasers, silicon PIN detectors, APD optoelectronic detectors, (In,Ga)As/InP long-wavelength PIN and ADP detectors, and a number of special junction-laser applications. Research has been conducted on basic physical problems relating to junction-laser behavior, e. g., output mode control, laser transient response, thermal characteristics, aging characteristics, and mechanism of failure.

Optical bistability and related device research has been a special problem under investigation at the institute for the past few years.

As the result of research over the years, microwave oscillators and detectors that work at wavelengths of 4, 3, and 2 mm (150 GHz) have been developed successively and put to use. Research is now progressing towards submillimeter devices. Also, research is carried out on millimeter-wave integrated circuits (MMICs), InP heterojunction devices, and the development of trapped plasma avalanche triggered transit (TRAPATT) oscillators with higher power and higher frequency. Recently work on high electron mobility transistors (HEMT) devices has also started.

Special ICs are developed in research projects for further development of DYL circuits (an innovation achieved at this Institute) on the one hand and radiation-resistant CMOS circuits on the other hand.

The institute did research on gas-sensitive sensors for a number of years and produced sensors for use in industry. More recently, research work has started on various types of sensors, including optical fiber thermal sensors, Hall-effect sensors, and ion-sensitive and biological enzyme-sensitive sensors.

A group carrying out original theoretical research on computer-aided design (CAD), relating to VLSI developed a few years ago, has proposed a new and advanced method for IC layout. Now, work is underway to implement their theoretical results for practical CAD applications.

4. Semiconductor electronics

Historically research has been mainly directed toward instrumental application of semiconductor devices and advanced measuring instrumentation and technology. The following are typical achievements,

- construction of the early nanosecond "samploscope"
- microwave beacon used in the early satellites
- measurement and characterization of dynamic characteristics of ICs
- boxcar averager
- logic analyzer.

Now research work is extended over a wide range of subjects, such as technology of high-speed and high-current pulses, detection of weak signals, optical fiber communication, optical logic, microcomputer applications in industrial process control and in measurement technology, and industrial application of semiconductor sensors.

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NATIONAL LABORATORY FOR SUPERLATTICES AND MICROSTRUCTURES (NLSM), INSTITUTE OF SEMICONDUCTORS, ACADEMIA SINICA, BEIJING

Semiconductor superlattices and microstructures are recognized in China to represent an important and fast developing frontier in modern solid-state sciences. The research of this national laboratory focuses on low-dimensional semiconductor microstructures that are grown by state-of-the-art growth technologies such as MBE and MOCVD. In broad-brush, the scope of the research includes semiconducting materials and semiconductor physics and devices based on semiconductor microstructures.

After a preliminary stage of development centered on MBE growth apparatus and technology, research on semiconductor superlattices and microstructures was launched as a basic-research project of key priority at a national level in 1986. Significant progress has been achieved in the many fields, including theoretical and optical spectroscopy studies on electronic structures, lattice dynamics optical transitions, and energy relaxation of photo-excited electrons in superlattices and quantum wells; quantum transport and other electronic behavior of low-dimensional electronic systems; growth technologies and material characterization of MBE-grown superlattices and multilayered heterostructures; new electronic and optoelectronic devices based on superlattices and quantum wells. During this period, over 200 scientific papers have been published.

On this basis, a new National Laboratory for Superlattices and Microstructures (NLSM) was established on April 17, 1989 at the Institute of Semiconductors, Chinese Academy of Sciences. The motivation for the laboratory is to form a well equipped national research center in the field of semiconductor superlattices and microstructures. While technically based on the development and continuous refinement of MBE and MOCVD technologies, the main thrust of the laboratory is on basic physical research of new features of various low-dimensional systems, realized in semiconductor superlattices and multilayered microstructures, and their potential for applications in electronics, optoelectronics, and photonics.

Scope of the Scientific Program

The main fields of investigation covered at the laboratory are as follows:

- Theoretical studies on electronic structures, elementary excitations and interaction processes, as well as transport properties in low-dimensional semiconductor structures.
- Spectroscopic investigations, including conventional and time-resolved photoabsorption and photoreflection spectroscopies, Raman spectroscopy and magneto-optic spectroscopies used in combination with temperature, pressure, and electric- or magnetic-field modulation techniques. Research topics consist of energy band structures, intrinsic and extrinsic recombinations, dynamics of photo-excited electrons and nonlinear optical properties in semiconductor superlattices and quantum wells.
- Quantum transport (parallel and perpendicular to interfaces) and their relevance to dimensional size and underlying physical processes.
- Investigation of electronic properties and behaviors of impurities, defects and deeplevel centers related to MBE- and MOCVD-grown materials.
- Material growth and the technologies of various low-dimensional semiconductor structures with artificially tailored band structures.
- Physical studies of processes underlying superlattice- or quantum-well-based devices.

Facilities

The most important instruments and equipment available at the laboratory are:

- VAX 3500 computer system
- Time-resolved optical spectroscopy system equipped with synchronously pumped mode-locked dye laser, double-grating monochromator, and 10K cryogenic refrigerator;
- Raman spectroscopic system and photoluminescence spectrometer at high pressure
- Modulation and infrared spectrometer composed of monochromator, 10 K cryogenic refrigerator and detector, with computer data-acquisition system
- Far-infrared cyclotron resonance and magneto-optical spectroscopy system including a far-infrared molecular laser and 8-T superconducting magnet system
- Various computerized DL-TS junction spectrometers

— Eight-T/12-T superconducting magnet system, including 0.3K 3He low-temperature insert, 4.2K to 300K variable temperature insert, and computer data-acquisition systems
— Molecular-beam epitaxy growth systems.

Welcome to NLSM

Scientists worldwide are cordially invited to work at the laboratory. A limited research grant can be awarded by the laboratory to cover the costs of expendable supplies and usage of the costly instruments and equipment available at the laboratory and at the institute while recipients of grants conduct their research on a specific project at the laboratory.

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NATIONAL LABORATORY FOR SURFACE PHYSICS, ACADEMIA SINICA, BEIJING

The National Laboratory for Surface Physics (NLSP), Academia Sinica, was established in 1987. Research covers a wide field of experimental and theoretical studies on surface and interface physics, with emphasis on application-oriented research. These include semiconductor superlattices, metal-semiconductor interfaces, transition-metal surfaces and interfaces, studies of single and multilayer thin films, and adsorption of gas on solid surfaces.

The NLSP research programs fall under five main headings.

Surface and interface studies of new materials

Research studies are conducted on the surfaces and interfaces of varied materials. The formation and behavior of interfaces are studied in detail by surface techniques at the atomic scale. The behavior of interfaces is quite different because of the differences in preparation technology and the materials that form interfaces. The physical and chemical properties of interface are investigated to provide the basic theory and a model to solve problems in practical interfaces such as interfaces in multilayers of semiconductor devices, and the composite materials of heterogeneous catalysts.

Surface theory

The proposed jellium-slab model is used with the linearized augmented-plane-wave (LAPW) method for energy-band calculations to investigate compositions, structures, and electronic states of clean and absorbed surfaces of metals, semiconductors and their compounds. Meanwhile, the ASED-molecular orbital method is used to discern the relation between charge transfer and coverage in the complex coadsorption systems. Also in connection with MBE growth of semiconductor multilayer thin-film materials, we have studied the interface stability, electronic structure, and local states and diffusion process of intrinsic defects. A structure of a photo-electric device with tunable superlattice energy gap with varying period is proposed.

High-T_c Superconductive Thin-Film Research

The composition, valence electron state, band structure, oxygen deficiency, temperature dependence, and element substitution of high T_c superconductors have been studied by surface photoemission electron spectroscopy and energy-loss spectroscopy. The relationship of the valence-electron states, band structure, and oxygen deficiency of the various atoms in the high T_c superconductors with superconducting characteristics has been investigated. All these have provided strong experimental evidences for the understanding of mechanisms of high-T_c superconductivity.

After having prepared the YBaCuO superconducting thin films by electron-beam evaporation, thus achieving zero resistance at liquid nitrogen temperature first time in China, BiSrCaCuO superconducting films have been fabricated by laser ablation. The field and temperature dependence of critical current of YBaCuO thin films, $J_c(H)$ and $J_c(T)$, have been measured.

Critical current Jc, was found out, was restricted by the weak link network between the grains in the films. The negative magneto resistance phenomena were obscured in low fields, which could be used in high-T_c superconducting devices. The metal-superconductor interface, interface chemistry, interface distribution, and interface diffusion have been studied systematically.

Some of the research studies were awarded first prize at the national natural science in 1989. In cooperation with the Royal Institute of Technology of Sweden, the Y- and Bibased superconducting thin films were fabricated by a special on-axis sputtering method with a stoichiometric target.

Metal-Semiconductor Interfaces

During the years, a major part of this research has been concerned with metal silicides. A variety of techniques have been used for studying the formation of thin silicide layer on Si and GaAs surfaces by thermal treatment or ion mixing of thin evaporated-metal films with particular emphasis on impurity effects.

Photoemission spectroscopy has been used to study the chemical behavior of interfaces formed by metal deposition (at 300 K, or at elevated temperatures, in an ultrahigh vacuum environment) on atomically clean Si or GaAs surfaces prepared by sputtering and annealing. Special attention has been given to the low-coverage regime. Recently, the rare-earth-metal silicides have been formed successfully. Future projects will be centered on the formation of epitaxial rare-earth-*metal silicides on Si.*

To support the technological programs at the laboratory, much effort was devoted to the quantitative analysis with auger-electron spectroscopy (AES) and secondary-ion mass (SIMS).

The research of the metal-semiconductor interface group can be broadly categorized into the following areas:

- Metal-semiconductor interface
- Silicide formation and impurity effects
- Interface physics (electronic structure, chemical bonding and atomic structure) of silicide-Si interface and bulk silicide-Si
- Formation and interface physics of silicide-GaAs
- Adsorption of gas on semiconductor surface or silicide surface.

Molecular-Beam Epitaxy Research

Studies have been made of growth kinetics, surface and interface phenomena, and device applications. Effusion cells, beam shutters, and a computer control system have been developed. (These components have been under embargo against exporting to communist countries.) Combining these components with an imported VG V80H MBE vacuum system, the first high-quality 3-in wafer MBE system in China was assembled at the NLSP, and laid a foundation for growing high-quality epitaxial materials and further research.

Modulation doped GaAs/-$Al_xGa_{1-x}As$ heterostructures have been grown with a room-temperature mobility as high as 7,000 cm^2/V-s at an electron concentration of 1×10^{12} cm^{-3}, the best performance reported in China.

Modulation doped pseudomorphic In GsAs/AlGaAs materials grown at NLSP also set the highest standard in China. Pseudomorphic InGsAs/AlGaAs materials are used for pseudomorphic high electron-mobility transistors (P-HEMT). These materials are grown in 2-in. wafers without using indium binding. The uniformity in thickness, carrier concentration, and electron mobility are within 3% across the whole wafer. The oval defect density of MBE layers produced in this MBE system is below 300 per cm^2. All these specifications are among the best records in China.

For photoelectronic device materials, GaAs/AlGaAs quantum-well laser materials and strained InGaAs/GaAs quantum-well laser materials with low threshold current have been successfully grown. Both materials have been made into laser devices with the best specifications in China.

In addition to providing materials for device groups, multiple quantum well (MQW) IR detectors have been fabricated internally, and have achieved a peak detectivity value of $D = 5 \times 10^{10}$ cm $Hz^{1/2}/W$ at 77K with a peak wavelength of about 8.3 μm. It is claimed that this result surpassed the best value reported from Japan, and is close to the best value reported in the world.

Not only studies on device applications but also basic research on electronic structure and crystal structure of epitaxial materials have been conducted. Studies have been made of the structural stability and the effect of strain on electronic structures in strained GaAs/InAs and GaP/InP superlattices.

The local electronic structures of impurities and of intrinsic defects have been studied in superlattices.

Interfacial strains in internally grown GaAs/Si heterojunction materials have been studied. To improve growth process of GaAs on Si, the passivation of Si(100) with As has been studied, and methods for controlling oxygen contamination have been developed.

In-depth research on GaAs1-xPx, and AlxGa1-xP has been conducted by using photoelectron spectroscopy. It has been concluded that the variation of their band gaps with composition is due mainly to the valence band set backs. This discovery is very important for studies of band discontinuity at heterojunctions.

Extensive research on reflection-electron microscopy (REM) of epitaxial multilayer materials has been conducted. In conclusion, the strain field induced by misfit dislocations affects the surface growth rate. The existence of localized strain fields at the interface of a dislocation-free pseudomorphic heterostructure has been shown. A new technique has also been developed to examine the cross section of an MQW device during the device fabri-

cation by using REM so as to have a precise control of the fabrication process.

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OPTOELECTRONICS NATIONAL LABORATORY, INSTITUTE OF SEMICONDUCTORS, ACADEMIA SINICA, BEIJING

The award of National Laboratory status by the CAS was shared by the Institute of Physics, Tsinghua University, and Jilin University. The part physically located at the Institute of Physics, headed by Professor Zhuang Wanru, benefits from close collaboration with the laboratories of the Institute of Semiconductors. For example, using MBE-grown material from the Institute of Semiconductors, Professor Zhuang's group has fabricated a bi-stable laser device, using an edge-emitting single-mode laser and an electrically or optically controlled absorber on the same chip.

In the picosecond spectroscopy laboratory, 10-ps laser pulses are used for measuring fluorescence-decay times in magnetic fields up to 7 T. Shortage of liquid helium limits the use of low-temperature experimentation, however, and low-temperature transport measurements must be done elsewhere.

Research in this group includes studies of p-i-n structures in which the intrinsic region is a superlattice.

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BEIJING VACUUM ELECTRONICS RESEARCH INSTITUTE, MINISTRY OF MACHINERY AND ELECTRONICS INDUSTRY, BEIJING

An example of research institutes outside CAS is BVERI, one of 50 research institutes of this Ministry, each with more than 2000 employees. Headed by Mr. Liao Fu J., BVERI has a varied research program of fundamental and applied research. Located in the northeastern area of Beijing, not far from the Beijing International Airport, BVERI has about 2300 employees including 18 professors, 200 senior engineers, 400 engineers, and 400 technicians.

BVERI describes itself as a largescale composite electronics research institute engaged in the field of vacuum electronics. At its founding in 1956, it was dedicated to research in microwave tubes. The scope has gradually expanded to include research in microwave, laser, and vacuum technologies. New research institutes have been supported through transfer of several hundred employees from BVERI. Among the employees of BVERI, the mid-career gap is quite evident. There are experienced workers with 25 or more years experience, and there are young, recent graduates, but few at the intermediate levels.

Scientific research at BVERI encompasses technology research and new product development based on applied research, such as new types of microwave or other electron devices, microwave, vacuum, laser technologies, and application technology for microcomputers. A recent emphasis was placed on the area of vacuum electronic technology, for which they have developed a field-emitter array.

In the category of electron tubes, research programs support produces: Klystrons for low-intermediate and high-power applications, twystrons, helix line traveling-wave tubes (TWT), coupled cavity TWT, backward-wave oscillators, frequency-agile magnetrons, coaxial magnetrons, crossed-field amplifier tubes, microwave triodes and tetrodes, gas-discharge duplexers, hydrogen thyratrons, gas lasers, display devices, hollow cathode lamps, electrodeless lamps, various types of gauge tubes, and X-ray tubes are among the broad product line that is supported by active research programs.

In the category of instrumentation, the principal products are vacuum gauges, mass spectrometers, surface analysis instruments, and custom products. Several dedicated products are produced, such as power supplies, pulse modulators, and microwave swept-frequency signal generators. Composite technology products include computer-controlled electron-beam welders, laser cutting machines, and X-ray photoconductive pick-up nondestructive testing equipment.

Various wave-guide components and PIN-diode controlled attenuators for cm-wave and mm-wave frequency bands are produced. All these products are supported by internal

research and development programs. Applications have supported radar, communication, navigation, television transmission, microwave therapy, and measuring equipment development throughout China.

Along with product development, BVERI research programs include basic theory such as large-signal analysis for interaction of electrons and waves, the study and design of electron optics, the study and design of periodic magnetic field focusing, approximate calculation of microwave cavity, and transmission line study of high-voltage breakdown in vacuum, the study of cathode failure mechanisms, the spectroscopic study of microwave biological effects, and the linear theory of gyrotron amplifiers.

Experimental research efforts include automatic field-intensity testing, electron-beam analyzer, radial-gauge measurements of the velocity distribution of electrons in the gyrotron beam, Auger-electron energy spectral analysis, secondary ion-mass spectroscopy, microwave swept-frequency testing.

Other research efforts include research on metal-ceramic sealing, quartz-metal sealing, precision machining, electron-beam machining, ion-beam machining, and laser machining. Some of these efforts have also led to marketable products. International trade has also been emphasized.

The scientific staff has intensified international scholastic interactions with eastern and western universities in recent years. International research collaborations have been encouraged with European, American, Asian and Australian scientists. BVERI expresses a hearty welcome to colleagues, research institutes, plants, corporations, both domestic and abroad, for development of various versions of technical cooperation and scholastic exchange, and to cultivate all forms of sincere and friendly collaboration.

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SHANGHAI INSTITUTE OF TECHNICAL PHYSICS, ACADEMIA SINICA, SHANGHAI

Although time did not permit me to visit this institute, a discussion with Professor Yuan Shixin convinced me that worthwhile research in electronic-materials physics and engineering is underway there. Thus, I would like to pass along the contact information for Professor Yuan for those who may be interested in making contacts in the Shanghai area with one of the leading research institutes working in the area of electronic-materials research.

Professor Yuan's main interest is in growth of quantum-wells and other heterostructures in II-VI materials. He has grown epitaxial heterostructures of $(CdTe)_n(ZnTe)_m$ on CdTe substrates, where n,m are small integers. He plans to look more closely at the Hg-Cd-Te system in the future.

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PROFESSIONAL SOCIETIES

I would like to comment briefly on three Chinese professional societies that may offer assistance to foreign scientists seeking to make contact with counterparts in China.

Chinese Institute of Electronics

The CIE is an umbrella organization of scientific organizations throughout China that are involved in the science and technology of electronics. The CIE, directed by Dr. Han C. Hu, an alumnus of the University of Michigan (1941), and Ph.D. from the University of Illinois, Department of Electrical Engineering (1949). Dr. Hu is also Honorary Director of the Chinese Vacuum Society (CVS), Vice Chairman of the Exchange Activities Committee of the China Association for Continuing Engineering Education, Chairman of Education Activities Committee of CIE, and Technical Advisor of BVERI. Through his position in the CIE, Dr. Hu can be of great assistance in making the most appropriate contacts within the Chinese scientific community.

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Shanghai Association for Science and Technology

The Shanghai area contains many research institutes, universities, and high-technology industrial organizations that may be of interest to U.S. scientists. All come under the umbrella of professional organizations that advise on such critical issues as research directions and funding as well as provide a central meeting ground for joint planning and collaboration.

The Vice President of SAST is Shen Guo Xiong, an energetic leader who has recently been given management responsibility for Shanghai's new "science city" development across the river from the main part of Shanghai. That development may be one of the most important in China in the 1990s, as far as science and technology are concerned. It is planned to use various incentives to attract universities, research institutes, corporate research laboratories, and high-technology industries to the area, where Shanghai's huge work force of low-cost, well-trained labor and many scientists and engineers may be enlisted.

Contact is:

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Shanghai Institute of Electronics

SIE was founded in 1961 with the aim of unifying science and technology workers and to encourage modernization, world-orientation, and future orientation. Under the professional guidance of CIE, SIE's 600 members are all science and technology workers above middle rank. The guiding body is the Standing Committee, chaired by Professor Gang Ruan of Fudan University. As does SAST, SIE also encourages international scientific exchanges and collaborations.

For further information, contact:

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Dr. Victor Rehn is currently a liaison scientist with the Office of Naval Research Asian Office in Tokyo. He assumed this position in May 1991. Since 1965 Dr. Rehn has been a research physicist with the Naval Weapons Center, China Lake, California. He started there as a research physicist in the Semiconductor Physics Branch, then as a supervisory research physicist he headed the Electron Structure of Solids Branch and the Semiconductor and Surface Science Branch, both in the Physics Division, Research Department. Dr Rehn received his B.A. in physics at the University of California, Berkeley in 1953 and his Ph.D. in physics from the University of Pittsburgh in 1962. After completing his thesis research in nuclear quadrupole resonance studies of paradichlorobenzene and related materials, Dr. Rehn studied magnetoacoustic attenuation in metals at the University of Chicago. Upon moving to China Lake, he undertook research in electroreflectance of widegap semiconductors and insulators. Beginning in 1973, he participated in the establishment of the Stanford Synchrotron Radiation Laboratory and continued with the application of synchrotron radiation in research in semiconductor and semiconductor surfaces. In 1976 he initiated a research program in liquid-phase epitaxy, followed in 1984 by research in molecular-beam epitaxial growth and characterization of semiconductor materials and heterostructures. In 1987 he initiated research in the production of yttrium barium copper oxide superconductive thin films using excimer-laser ablation.

NATIONAL DEFENSE ACADEMY OF JAPAN: Undergraduate and Ocean Science and Engineering Graduate Programs

Japan's Defense Academy in Yokusuka, south of Tokyo, trains officers for all three military services: Ground, Maritime, and Air. The program is strongly focused on Engineering with 14 major programs, but with 2 Social Science majors given at the undergraduate level. A Postgraduate Master degree program was started in 1962 and includes aerospace engineering, applied physics, geoscience engineering, materials engineering, and operations research. Ocean engineering programs are placed in both the Mechanical Engineering and Geoscience Engineering programs. This report focuses on the Ocean Sciences program. The research facilities are being modernized and expanded with several new flumes and test tanks for coastal engineering and ship hydrodynamic studies just completed. Computer image processing facilities that have been developed to support research in air and sea interactions, particularly during sea and ice conditions, recently have been improved. Underwater acoustics can be studied by using three high-pressure specially designed chambers.

Pat Wilde

INTRODUCTION

As of 15 August 1992, the Japanese government has authorized the use of the Japanese Self-Defense Forces as part of the peace keeping operations of the United Nations, initially in Cambodia. This is a controversial break with the tradition, anchored in the post-World War II Japanese Constitution, of military noninterference in the affairs of other nations. This policy was part of the downgrading of the military in Japan and its influence in the government after their defeat in World War II. The Japanese government was criticized during the Gulf War of 1990-91 for not taking a more active role on the Allied side, that is sending combat troops, particularly since Japan had vital energy supplies and interests in the Gulf. Also, Japan would like to play a more important role internationally, commensurate with its global economic power, perhaps even gaining a seat at the United Nations Security Council. With these criticisms and goals in mind, the Japanese government has decided to take the unpopular step of sending troops outside Japan and risk the charge of reinstituting militarism. Thus the role of the Self-Defense Forces will change in the post-Cold War world, and the training of its officers will come under increasing scrutiny. The following is a brief glance at the formal officer training academy and reflects the pre-peace keeping role of the Self-Defense Forces.

The Japanese National Defense Academy is the combined service academy of Japan training cadets to become officers in the Ground, Maritime, and Air Self-Defense Forces. The campus is situated on 160 acres on the Obara-dai plateau by the shores of Tokyo Bay, just south of the American Naval base at Yokusuka. Originally, the location was part of the harbor defense system for Tokyo Bay. After World War II it

was used as a U.S. artillery base until turned back to the Japanese government. The Academy, initially called the National Safety Academy, admitted the first class of 400 cadets in April 1953. In the same year, the authorized strength was increased to 530 to accommodate cadets for the newly formed Air Defense Force. Initially, the curriculum was only in Engineering; however, in 1974, Social Sciences courses were added. Postgraduate education with a Master degree program was started in 1962. This curriculum includes aerospace engineering, applied physics, electronic engineering, geoscience engineering, materials engineering, mechanical engineering, and operations research. In the spring of 1992, the first women cadets were enrolled. Thus the Academy is an amalgam of West Point, Annapolis, and Colorado Springs, plus a bit of the Naval Postgraduate School at Monterey. Unlike the American military academies, there is no service commitment after graduations. In recent years, up to 20 percent of the class have declined commissions. This is understandable, considering the strong antimilitary feelings in Japan after its defeat in World War II.

CURRICULUM

Undergraduate

The Academic Department includes Liberal Arts, Social Sciences, Foreign Languages, Physical Education, Mathematics and Physics, Electrical Engineering, Mechanical Engineering, Civil Engineering, Applied Chemistry, Applied Physics, Aerospace Engineering, Computer Sciences, Material Science and Engineering, Ground Defense Science, Maritime Defense Science, and Air Defense Science.

Table 1 — Major Degrees Distributions

Major	Ground Force	Maritime Force	Air Force	Total
ENGINEERING				
Math and Phys.	11	4	5	20
Geoscience	8	3	4	15
Electrical Eng.	18	7	8	33
Electronics	18	7	8	33
Communicat. Eng.	18	7	8	33
Mech. Eng.	20	8	5	33
Precision Eng.	20	8	5	33
Mechanical Sys.	20	8	5	33
Civil Eng.	30	0	3	33
Applied Chem.	23	5	5	33
Applied Phys.	17	6	10	33
Aerospace Eng.	12	15	35	62
Computer Sci.	19	6	8	33
Material and Eng.	19	6	8	33
SOCIAL SCIENCE				
Management Sci.	24	5	6	35
Internat. Rel.	23	5	7	35
Grand Total				530

Major degrees are assigned upon instruction from the National Defense Agency and the present distribution is shown in Table 1.

Postgraduate Studies

A Postgraduate program in Science and Engineering was started in 1962. It was open to National Defense Academy graduates and civilian officials in the National Defense Agency with a bachelor degree. About 90 students are selected each year through an entrance examination. The program lasts two years and is intended to be the equivalent of a master program. Candidates are expected to complete 32 credits, write a thesis, and pass an examination for graduation. Departments with Major degrees areas of study are as follows:

Aerospace Engineering:

Aerospace Vehicle Dynamics
High Speed Aerodynamics
Propulsion Engineering
Guidance and Control
Servomechanisms
Helicopter Engineering I
Helicopter Engineering 11

Applied Physics:

Solid-State Physics for Electronics
Underwater Acoustics
Ballistics and Fire Control
Applied Electromagnetics
Materials Science
Combustion Science

Electronic Engineering:

Signal Transmission
Communications Theory
Electronic Circuits

Electronic Materials
Electronic Computation
Microwave
Precision Measurements
Space Communications

Geoscientific Engineering:

Structural Engineering
Structural Dynamics
Soils Engineering
Meteorology
Aerology
Ocean Engineering

Materials Engineering:

Rocket Propellants
Explosives
Fuels
Organic Materials
Radiation Measurements

Mechanical Engineering:

Material Science of Iron and Steel
Prime Mover
Automatic Control
Precision Mechanics
Land Vehicle
Naval Hydrodynamics
Ship Structure and Design
Strength and Fracture of Material
Machining and Forming

Operations Research:

Operations Analysis
Applied Probability
Systems Engineering
Planning and Control

Programs in Ocean Science and Engineering are divided among several departments: Applied Physics (Underwater Acoustics); Mechanical Engineering (Naval Hydrodynamics and Ship Structure and Design); and Geoscientific Engineering (Meteorology, Ocean Engineering).

OCEAN RELATED RESEARCH

Research at the Defense Academy is of two types: 1. long-term programs essentially equivalent to those done under professorial supervision at U.S. Universities, and 2. short term student projects. With only a master program the student projects must be doable in the short two-year period allotted each graduate student. Accordingly, the Defense Academy's graduate program is very similar to that of the Monterey Naval Postgraduate School.

Applied Physics—Underwater acoustics, Prof. Toshimitsu Kikuchi. Facilities include a high-pressure chamber (3000 m) for testing transducer materials at 100 and 300 khZ and two sound scattering pattern chambers.

Geoscientific Engineering—Meteorology, Prof. Genichi Naito (Dept. of Mathematics and Physics) Research is done in three areas:

1. Atmospheric boundary layer physics
   a. Turbulent characteristics of wind velocity, heat, and moisture above the ocean;
   b. Momentum and heat transfers between lower atmosphere and sea surface; and
   c. Strong wind in severe storms for design of big structures.
2. Oceanography
   a. sea ice dynamics;
   b. wind waves.
3. Image data analysis on various kinds of Earth science phenomena by using an image processing facility/computer. Real data are taken at a site at the northern tip of Hokkaido. Much of the sea ice studies is done from information collected from periodic photo flights near the research data station.

To handle and process these photographs and other graphic sources, the Academy has a new (1991) image processing facility center based on the R-VAX/7100 system. The system consists of three parts,

1. high-speed, powerful image processor, nexus,
2. system-control computer, VAX4000,
3. four engineering workstations for displaying and analyzing image data.

All computers communicate with each other through a network. Various peripherals attached to VAX4000, including laser writers and magnetic tape drivers, are reachable from any computer in the system. Image displaying and analyzing software installed in VAX4000 are also accessible under VAX/VMS operating system from engineering workstations in our system. The image processor, nexus, adopts a 32-bit parallel cpu, T414 (Inmos Corporation), as a display processor and is especially suited for image processing. The nexus supports various styles of image data input/output. The NTSC/PAL camera, digital camera (CCD camera) and image scanner are prepared for data input, and the 35-mm and polaroid cameras are available for the representation of the results of image data analysis. Software for image data analysis is also installed.

In cooperation with Dr. Y. Sasaki of Japan Marine Science and

Technology Center and Dr. H. Nakamura at the National Research Institute of Earth Sciences and Disaster Prevention, current research is done on turbulent structure of wind flow over sea ice and sea ice image processed data on roughness, areal coverage, and other properties derived from air photographs.

Geoscientific Engineering—Ocean Engineering, Prof. Toshiyuki Shigemura, Prof. Kenjirou Hayashi, and Prof. Kouji Fujima (Dept. of Civil Engineering). Research is done n a combination of Coastal Engineering field studies and experimental activities due in the Academy's newly constructed test tanks. Prof. Shigemura is conducting long-term studies on the shoreline profile of the island of Iwo Jima. This active volcanic island is rising while its shape is continuously being modified by coastal erosion and depositional processes. The site of the famous battle in World War II, the landing field on the island presently is being used by U.S. pilots and by Japanese armed forces for training exercises. Prof. Hayashi is conducting two research projects.

1. Wave forces acting on a cylinder in waves and its vibration looking at
    a. characteristics of flow around a vertical circular cylinder in waves;
    b. lift forces on a rigid vertical cylinder in waves;
    c. vortex-excited vibration of a vertical cylinder in waves; and
    d. forces acting on a vortex-excited vibrating cylinder in planar oscillatory flow.

2. Flow resistance in open channel, specifically flow induced vibration of a tree in an open channel. The amplification of drag force and lift force acting on a vibrating cylinder was evaluated.

These experiments are being conducted in the newly constructed 40-m open-channel flume with both wave and currents being potentially generated by computer controlled system. Professor Fujima is working on modelling the interaction of wind and waves with the long-term goal of wave prediction. In addition to the wave tank, the Ocean Engineering staff has available a recently constructed model basin where various scale model harbor facilities can be tested.

Mechanical Engineering—Two laboratories are doing research on Naval Architecture. The Structural Laboratory is using for student themes, the Stealth Submarine (Professor Kawabe) and the design of training sailing ships (Professor Mirigushio). The Ship Hydrodynamics Laboratory, housed in the same building as the Civil Engineering test tanks and the acoustic test chambers has a major theme of study of high-speed boats. Professor Bessho is doing the theoretical work, and Professor Suzuki is doing the experimental studies. Experiments are now being done in the new (March 1991) high-speed circulating water channel. The channel is 5-m long, 1.8-m wide, and 1.0-m deep with a designed maximum speed of 2.8-m/s. Professor Suzuki has developed a special dynamometer to measure ship resistance modifying the work of Professor Ikeda at Osaka University. The experimental dynamometer measures horizontal force, trim angle, and center of gravity rise, but it is not affected by the water level rise with changes in speed. Tests are now underway on the ship model with a set trim but free to heave.

SUMMARY

The Japanese Defense Academy will be entering a new phase of operations now that Japanese forces will be involved in United Nations peace keeping roles. However prior to that decision, in the summer of 1992, the facilities and particularly the graduate research facilities were being modernized. This upgrade, the free tuition, and the new status given the military may attract a wider variety of qualified students to seek a military career while obtaining an excellent Engineering and Research background.

Dr. Pat Wilde joined the staff of the Office of Naval Research Asian Office (ONRASIA) in July 1991 as a liaison scientist specializing in ocean sciences. He received his Ph.D. in geology from Harvard University in 1965. Since 1964, he has been affiliated with the University of California Berkeley in a variety of positions and departments, including Chairman of Ocean Engineering from 1968 to 1975 and Head of the Marine Sciences Group at the Lawrence Berkeley Laboratory (1977-1982) and on the Berkeley campus (1982-1989). He joined ONRASIA after being the Humboldt Prize Winner in Residence at the Technical University of Berlin. Dr. Wilde's speciality is in paleo-oceanography and marine geochemistry, particularly in the Paleozoic and Anoxic environments. He maintains an interest in modern oceanography through his work on deep-sea fans, coastal and deep-sea sediment transport, and publication of oceanographic data sheets showing the bathymetry with attendant features off the West Coast of the United States, Hawaii, and Puerto Rico.

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